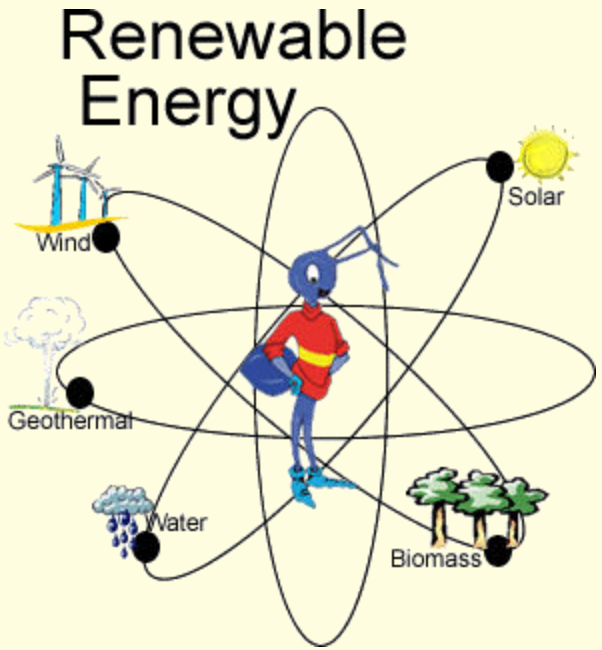
ENVIRONMENTAL SCIENCE

CHAPTER 13: Energy



Three Big Ideas from This Chapter - #1

E resources should be evaluated on

- potential supplies
- how much net useful E they provide
- **environmental impact** of using them

Three Big Ideas from This Chapter - #2

Using a **mix** of renewable energy:

- **Sunlight**
- Wind
- flowing water
- *sustainable* **biofuels**
- geothermal energy

can drastically reduce pollution, greenhouse gas emissions, and biodiversity losses.

Three Big Ideas from This Chapter - #3

Making transition to more sustainable E future requires **sharply reducing E waste**,

using a mix of environmentally friendly **renewable E resources**,

and **including harmful environmental costs** of E resources in their market prices.

Evaluating Energy Resources

Energy from the sun

Indirect forms of renewable **solar** energy

- Wind
- Hydropower
- Biomass

Commercial energy

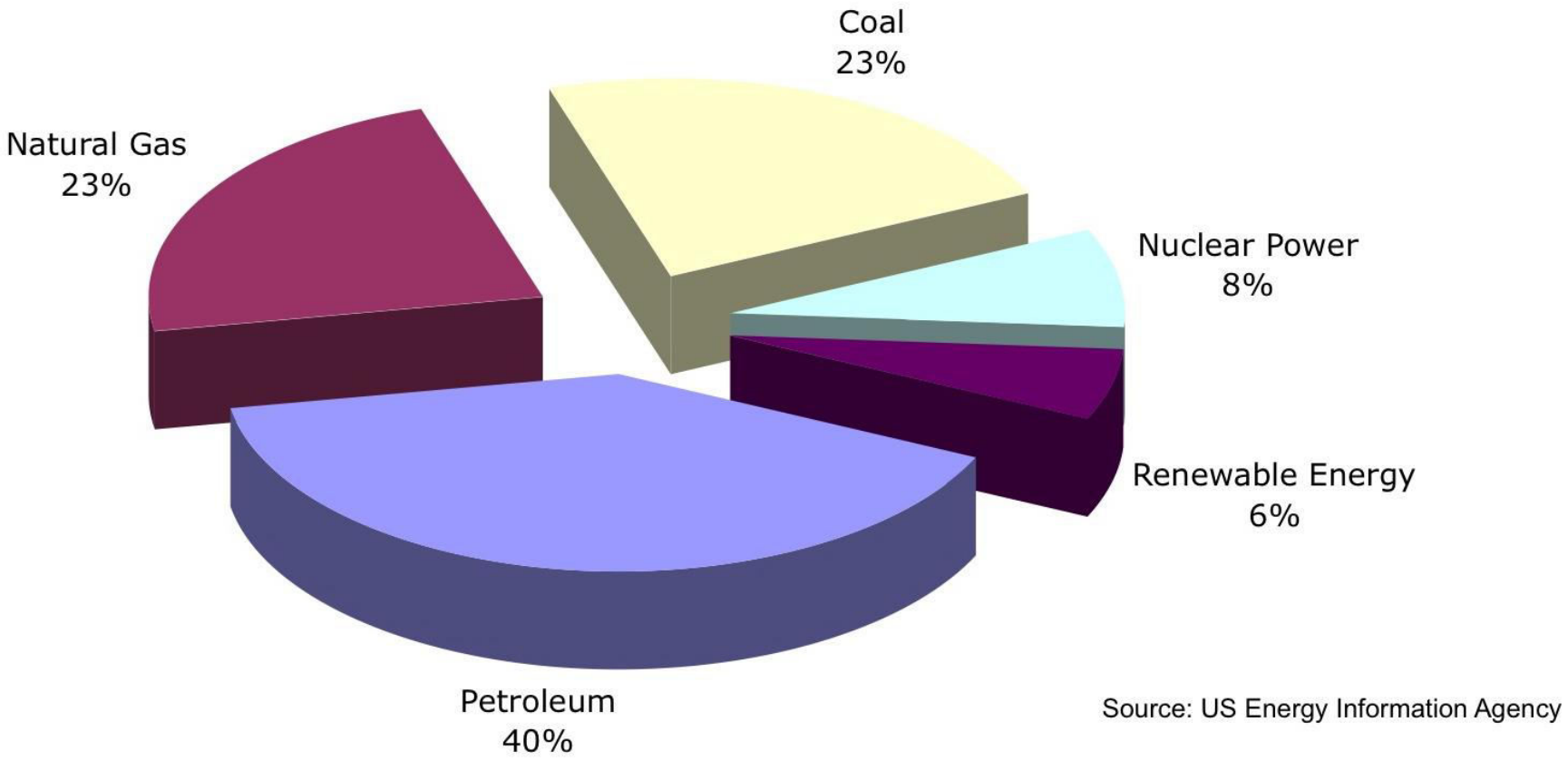
- Fossil fuels – non-renewable
- Nuclear – non-renewable

75% world's commercial E comes from **non-renewable fossil fuels**.

Rest comes from

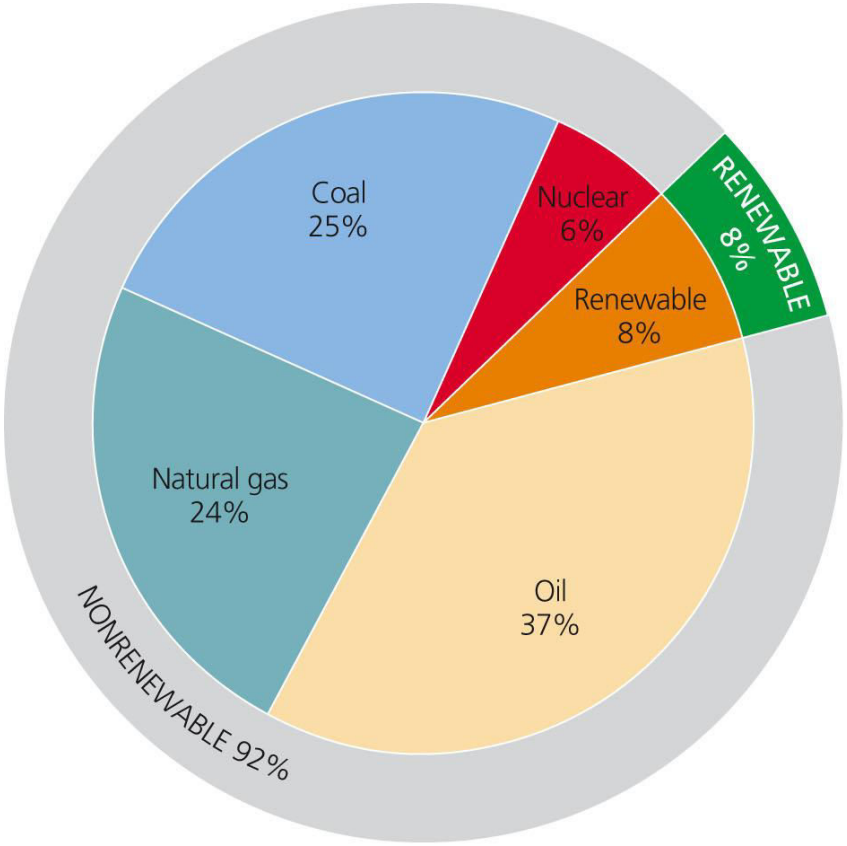
- **non-renewable nuclear fuel**
- **renewable sources**.

Figure 1: 86% of US Energy Consumption Is Fossil Fuels

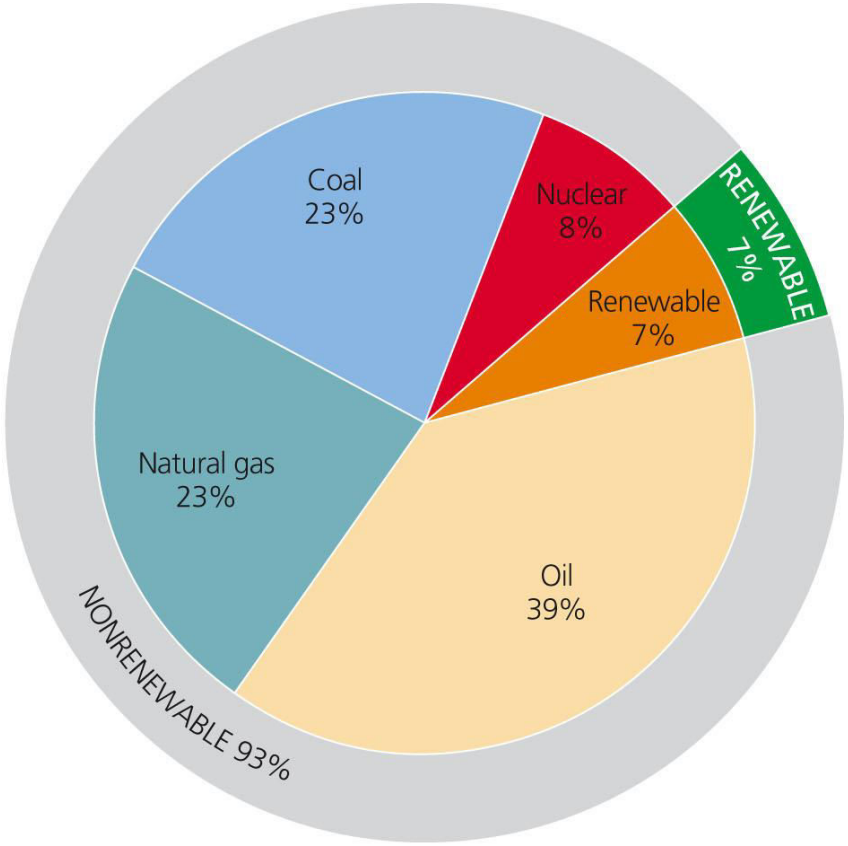


Source: US Energy Information Agency

Net E = high-quality E available from resource minus amount of E needed to make it available.

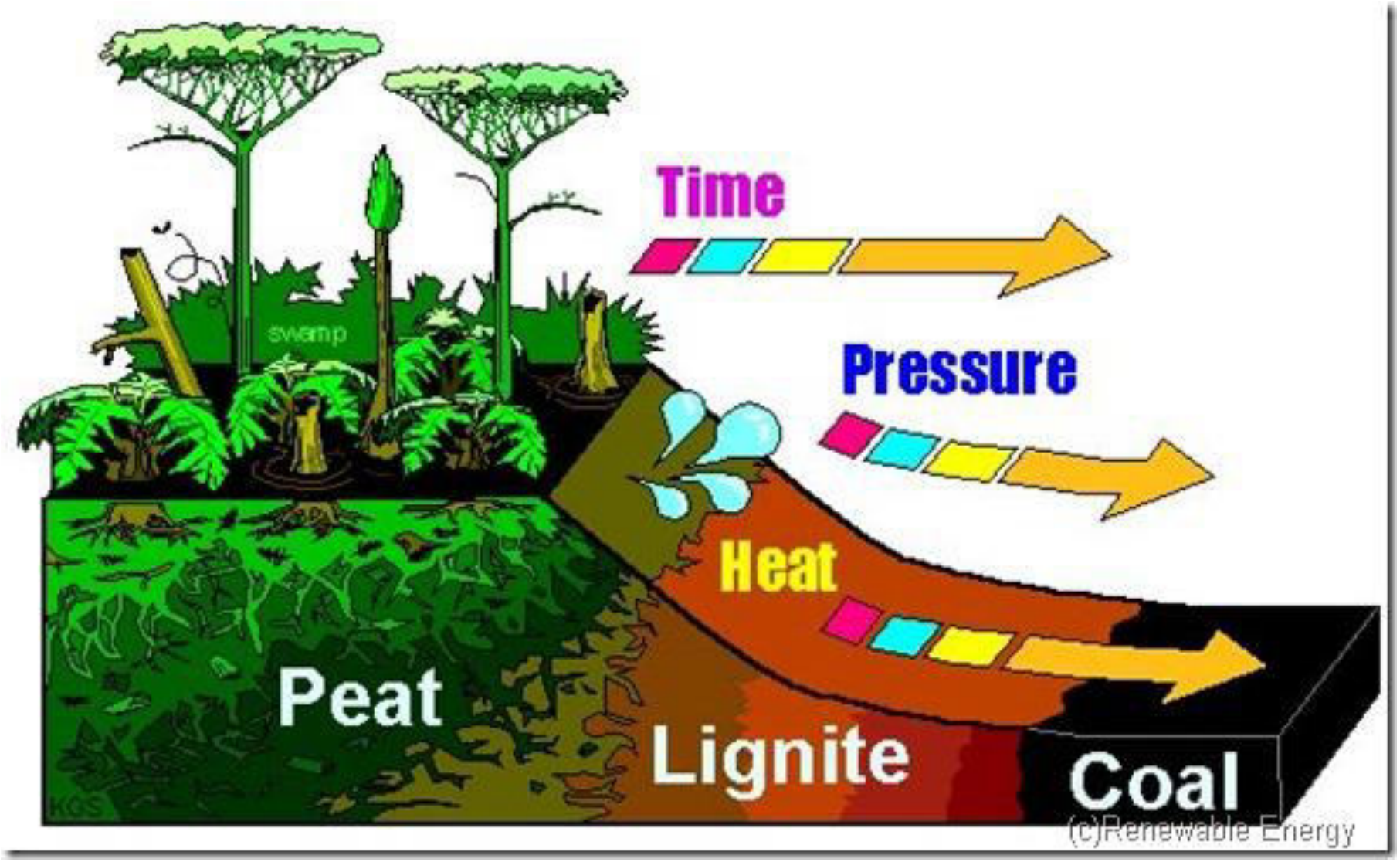


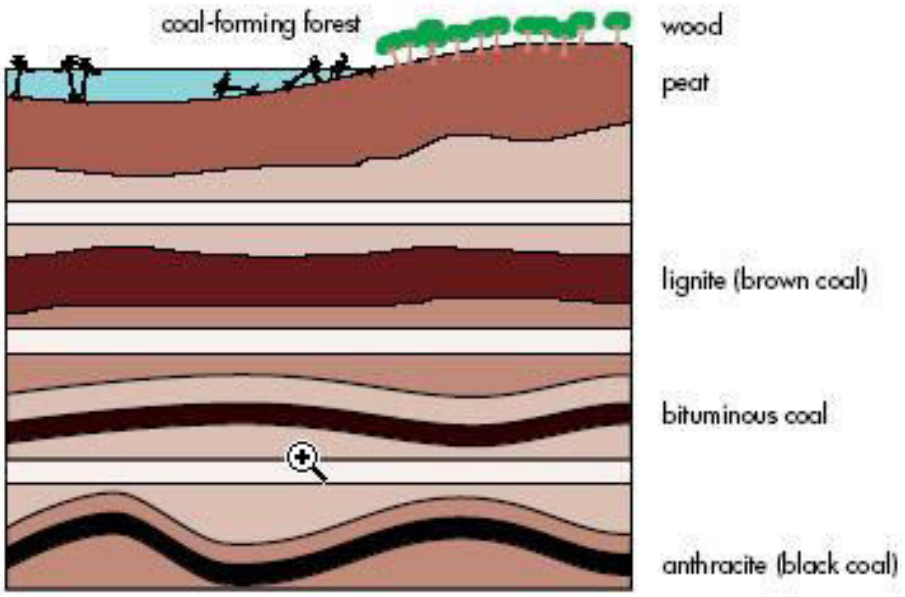
World 2007



United States 2007

Fig. 13-2, p. 298

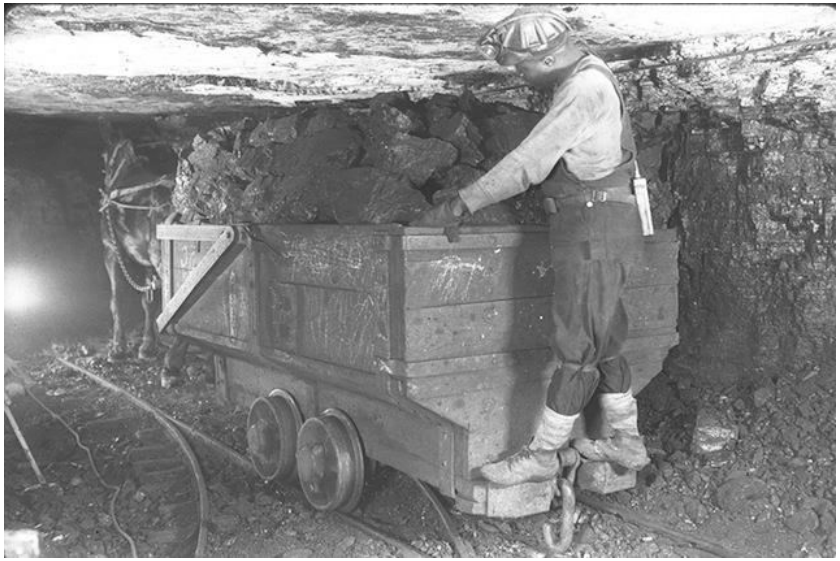

Time
Pressure
Heat
swamp
Peat
Lignite
Coal
(c)Renewable Energy



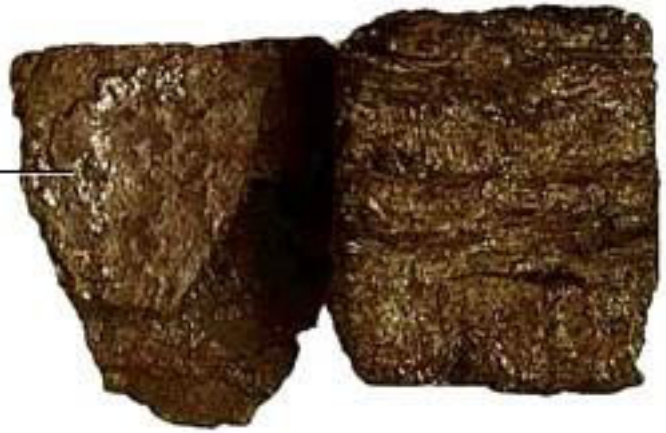
Coal is formed over millions of years from rotting plant material that accumulated in warm, muddy swamps

Moist, fibrous peat

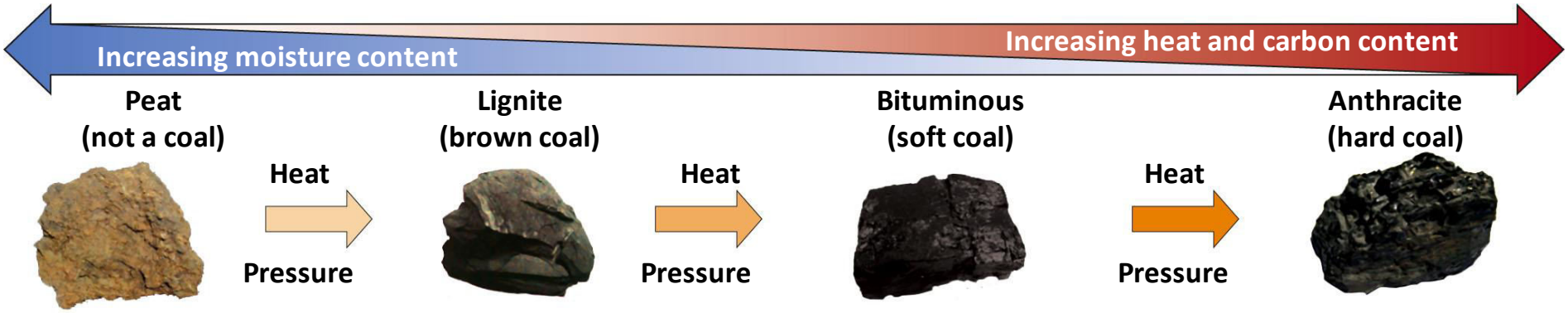
Lignite, or brown coal, is found nearest Earth's surface.



Bituminous coal is found deeper underground.



Hard, black anthracite is found the deepest underground.



Partially decayed plant matter in swamps and bogs; low heat content

Low heat content; low sulfur content; limited supplies in most areas

Extensively used as a fuel because of its high heat content and large supplies; normally has a high sulfur content

Highly desirable fuel because of its high heat content and low sulfur content; supplies are limited in most areas

Fig. 13-9, p. 305

Coal Is a Plentiful But Dirty Fuel

- Used in electricity production
- World's most abundant fossil fuel
- U.S. reserves should last ~ **250 years**
- Sulfur and particulate pollutants
- Mercury and radioactive pollutants

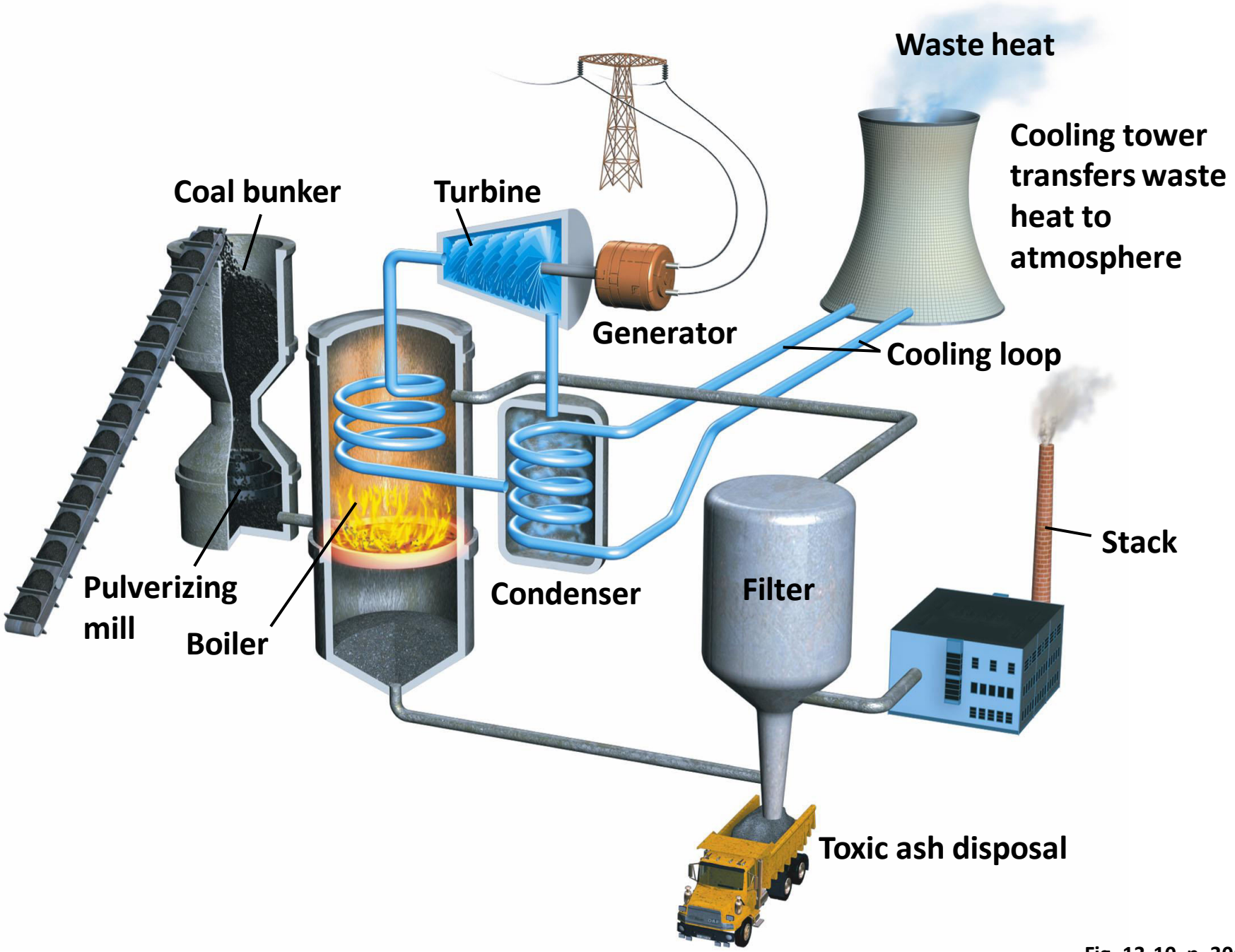


Fig. 13-10, p. 306

Coal Is a Plentiful But Dirty Fuel

- Heavy carbon dioxide emissions
- Pollution control and environmental costs
- China major builder of coal plants

Case Study: The Growing Problem of Coal Ash

- Highly toxic
- Often stored in ponds
  - Ponds can rupture
- Groundwater contamination
- EPA: in 2009 called for classifying coal ash as hazardous waste
  - Opposed by coal companies

Clean Coal Campaign

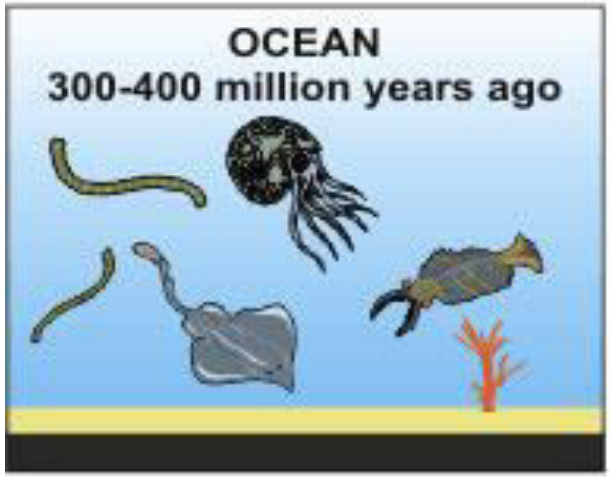
- Coal industry
  - Rich and powerful
  - Fought against labeling CO_2 a greenhouse gas

- "Clean coal" touted by coal industry
  - Mining harms the environment
  - Burning creates CO_2 & toxic chemicals

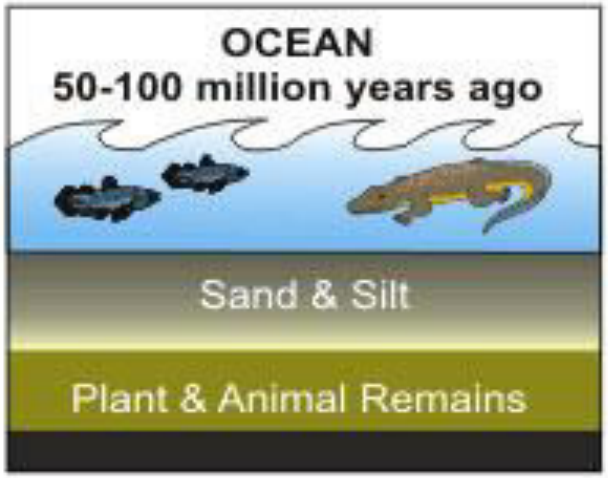
- Plan to capture and store CO_2

Converting Coal into Gaseous and Liquid Fuels

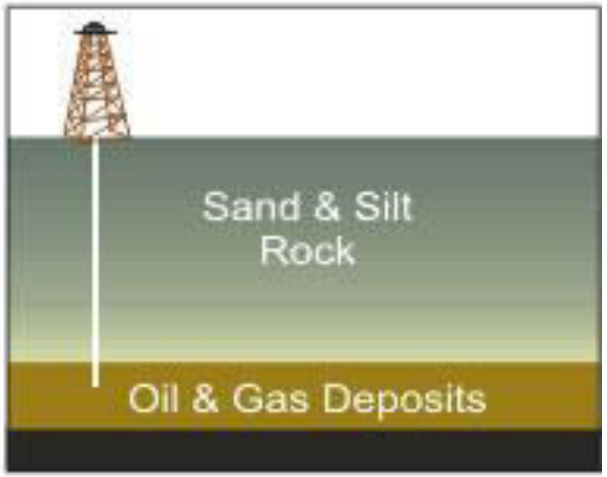
- Synfuels
- **Coal gasification**
  - **Synthetic natural gas (SNG)**
- **Coal liquefaction**
  - Methanol or synthetic gasoline
- Extracting & burning coal more cleanly



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

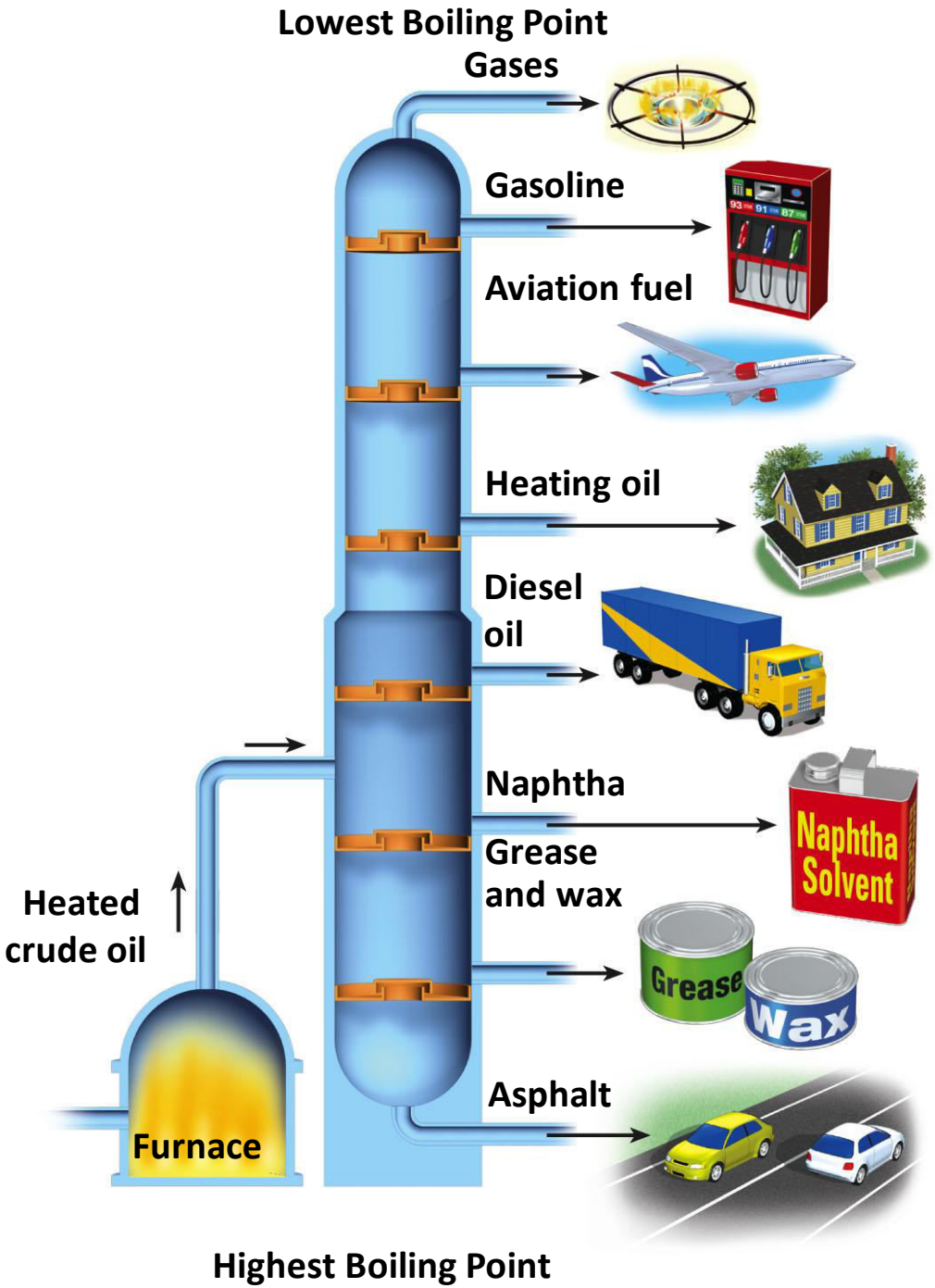


Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.



Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

oil formation


Lowest Boiling Point
Gases
Gasoline
Aviation fuel
Heating oil
Diesel
oil
Naphtha
Grease
and wax
Asphalt
Heated
crude oil
Furnace
Naphtha
Solvent
Grease
Wax
Highest Boiling Point

How Long Will Crude Oil Supplies Last?

Crude oil is the single largest source of commercial energy in world and U.S.

Proven oil reserves

- Can be extracted profitably at today's prices
  with today's technology
- 80% depleted between 2050 and 2100

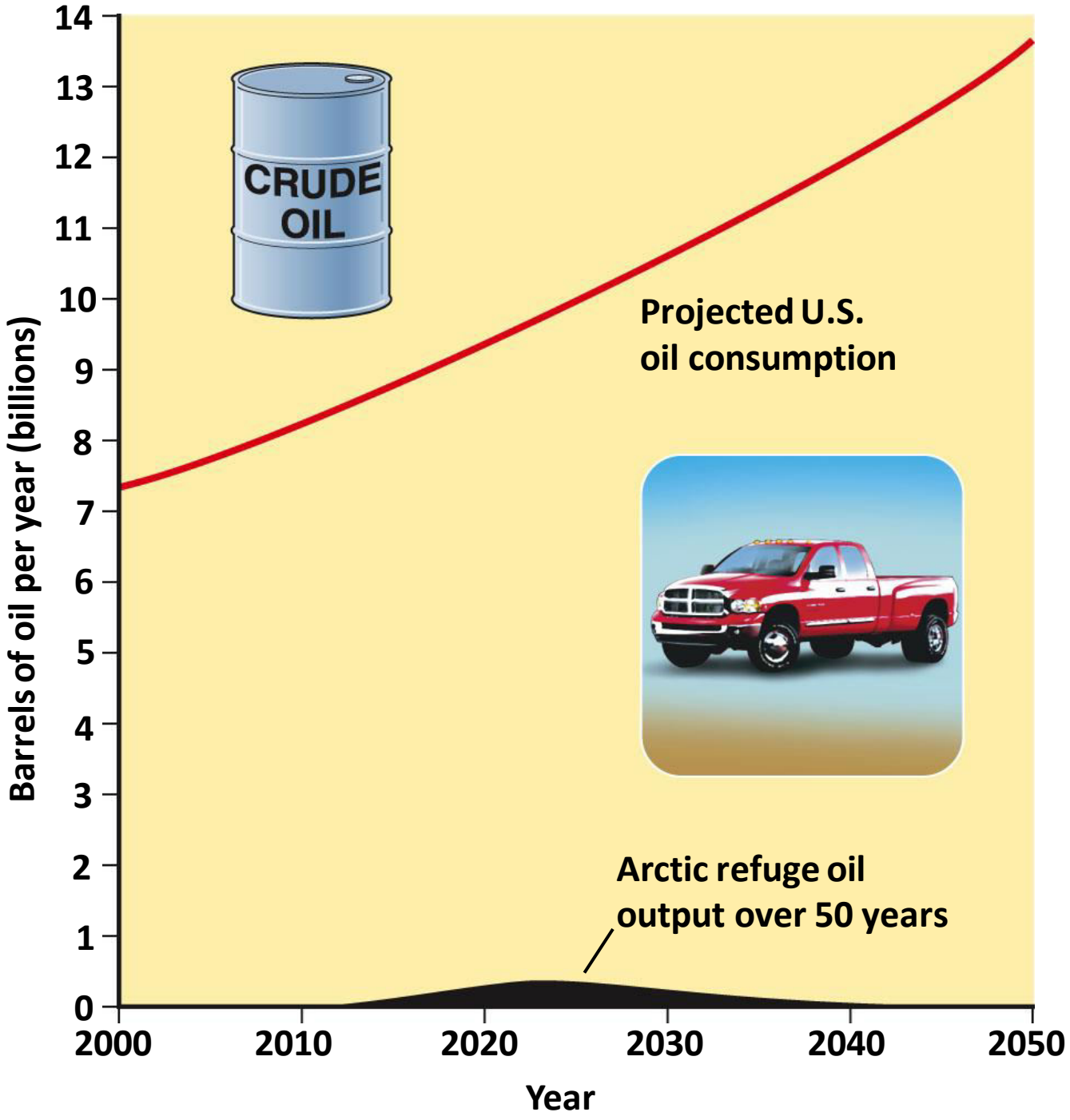

14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Barrels of oil per year (billions)
CRUDE OIL
Projected U.S. oil consumption
Arctic refuge oil output over 50 years
2000
2010
2020
2030
2040
2050
Year

Fig. 13-4, p. 301

US Oil Production and Use

- 93% of energy from fossil fuels
- 39% from crude oil

- **Produces 9%** of world's crude oil
- **Uses 25%** of world production

- Has 2% of proven crude oil reserves

Oil Sand and Oil Shale

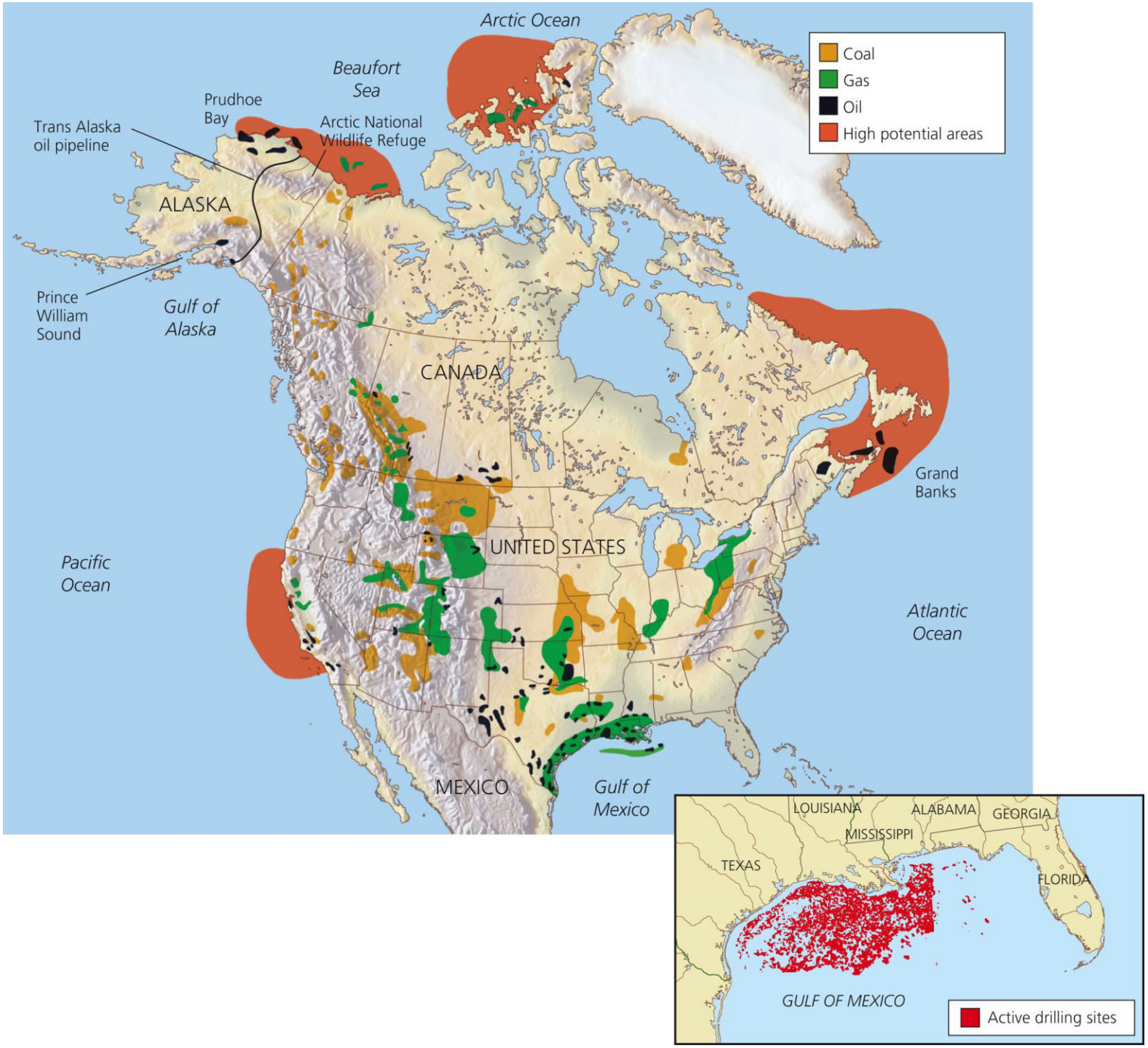
Oil sand (tar sand)

- Bitumen
- Kerogen

Shale Oil

- World reserves
- Major environmental problems

Fig. 13-6, p. 303

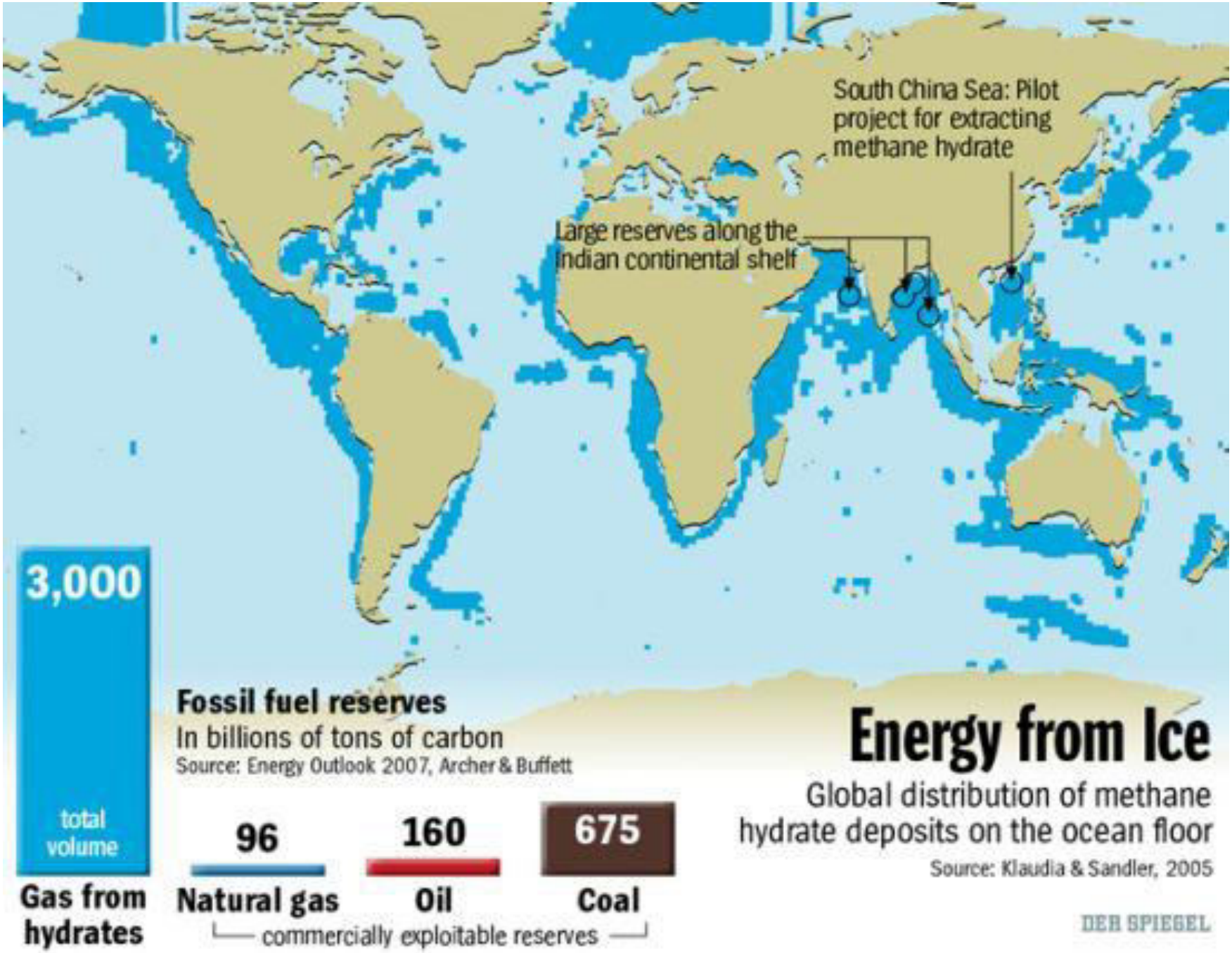

Arctic Ocean
Beaufort Sea
Prudhoe Bay
Trans Alaska oil pipeline
Arctic National Wildlife Refuge
ALASKA
Prince William Sound
Gulf of Alaska
CANADA
Grand Banks
UNITED STATES
Pacific Ocean
Atlantic Ocean
MEXICO
Gulf of Mexico
Coal
Gas
Oil
High potential areas
LOUISIANA
ALABAMA
GEORGIA
MISSISSIPPI
TEXAS
FLORIDA
GULF OF MEXICO
Active drilling sites

Natural Gas Is a Useful and Clean-burning Fossil Fuel

- Conventional natural gas
- **Unconventional** natural gas

Liquefied natural gas (LNG)

- Less CO_2 emitted per unit of E than with crude oil, tar sand, shale oil
- World supply of conventional natural gas: 62-125 years
- Unconventional natural gas
  - **Coal-bed methane gas**
  - **Methane hydrate**


South China Sea: Pilot project for extracting methane hydrate
Large reserves along the Indian continental shelf
3,000
total volume
Gas from hydrates
Fossil fuel reserves
In billions of tons of carbon
Source: Energy Outlook 2007, Archer & Buffett
96
Natural gas
160
Oil
675
Coal
commercially exploitable reserves
Energy from Ice
Global distribution of methane hydrate deposits on the ocean floor
Source: Klaudia & Sandler, 2005
DER SPIEGEL

What Are Advantages and Disadvantages of Nuclear Energy?

nuclear power fuel cycle:

- low environmental impact
- very low accident risk

What Are Advantages and Disadvantages of Nuclear Energy?

…but limited because of:

- high costs
- low net energy yield
- long-lived radioactive wastes
- vulnerability to sabotage
- potential for spreading nuclear weapons technology.

How Does a Nuclear Fission Reactor Work?

- Nuclear fission
- Light-water reactors
- Boil water to produce steam to turn turbines to generate electricity
- Radioactive uranium as fuel
- Control rods, coolant, and containment vessels

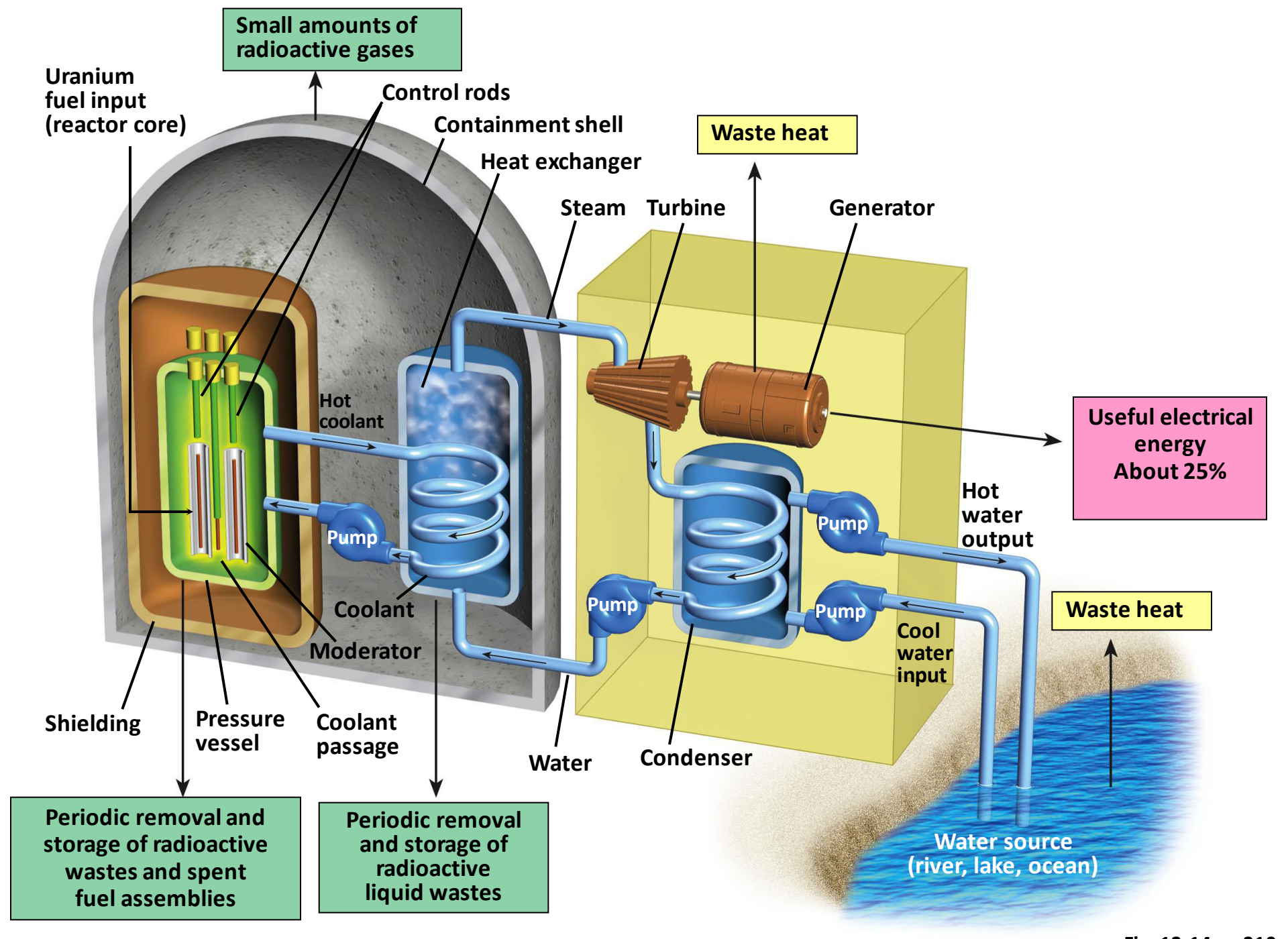


Fig. 13-14, p. 310

Safety and Radioactive Wastes

- On-site storage of radioactive wastes
- Safety features of nuclear power plants
- Nuclear fuel cycle
- Reactor life cycle
- Large amounts of very radioactive wastes

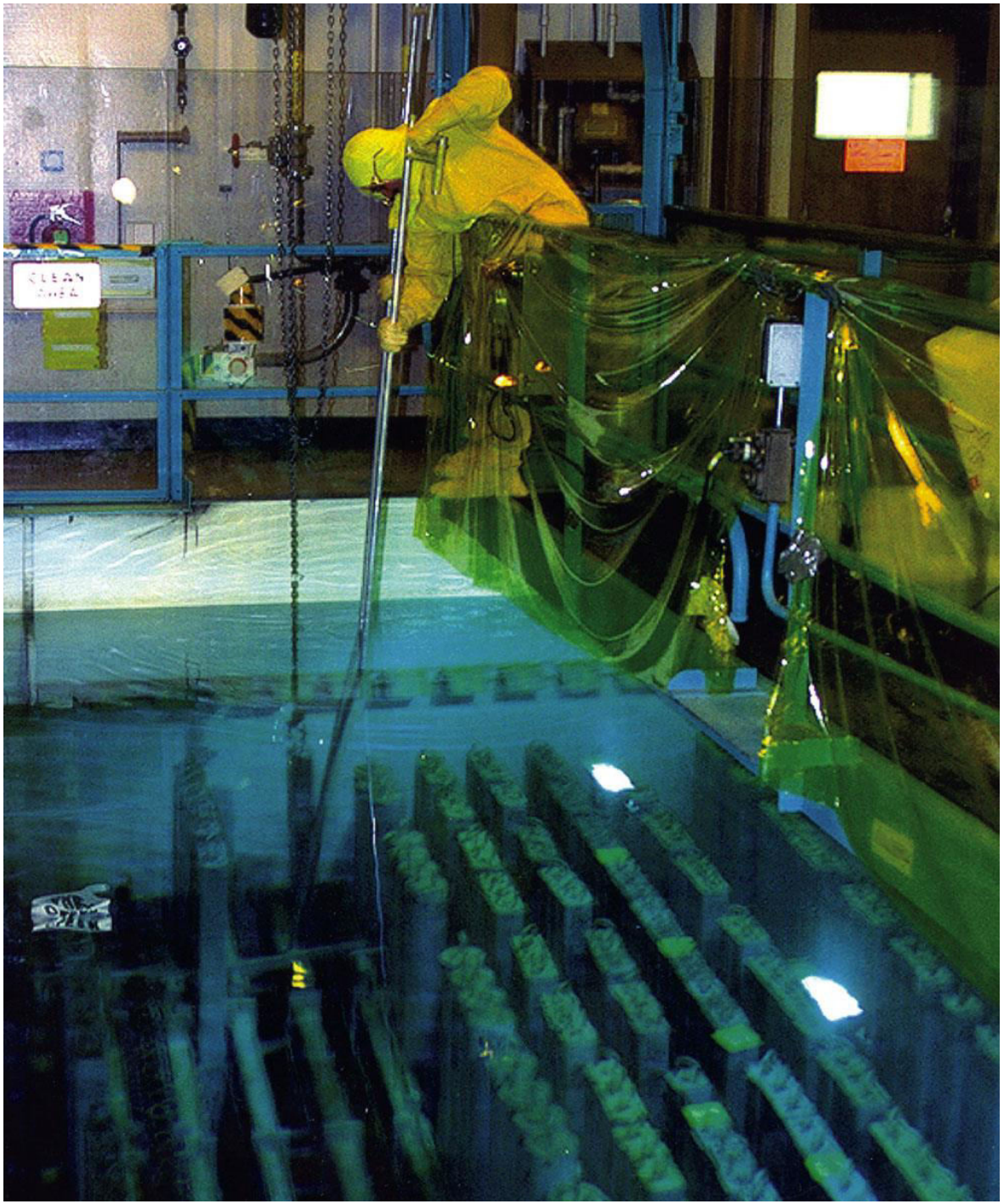


Fig. 13-15, p. 311

Fig. 13-15, p. 311

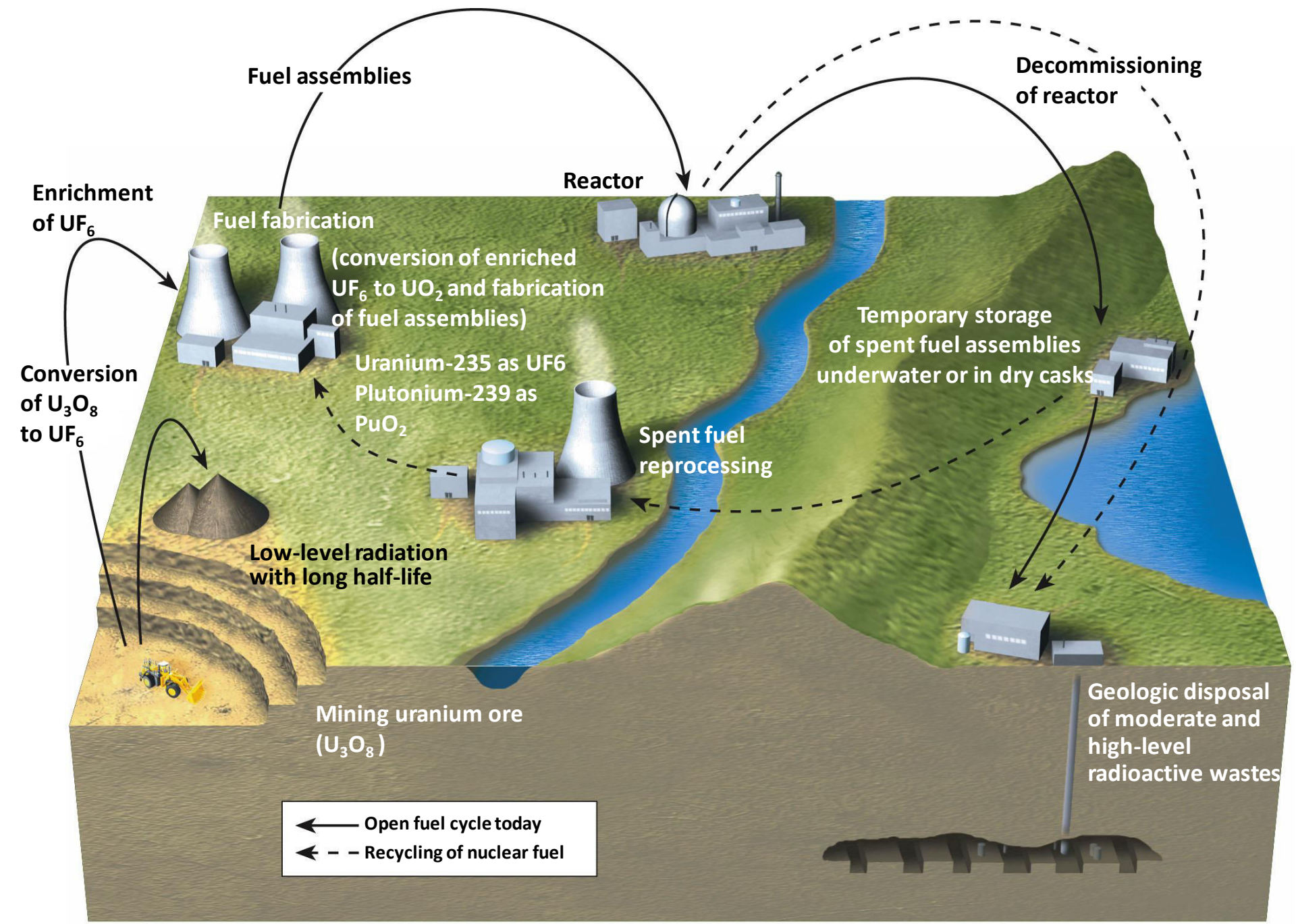


Fig. 13-16, p. 312

What Happened to Nuclear Power?

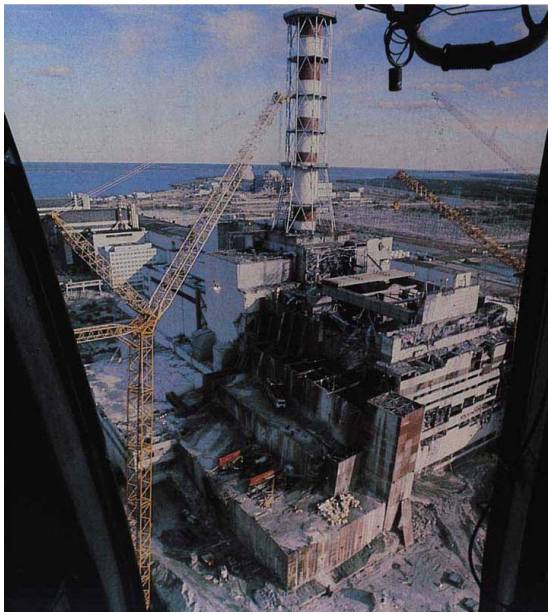
- Optimism of 1950s is gone
- Comparatively expensive source of power
- No new plants in U.S. since 1978
- Disposing of nuclear waste is difficult
- Three Mile Island (1979)

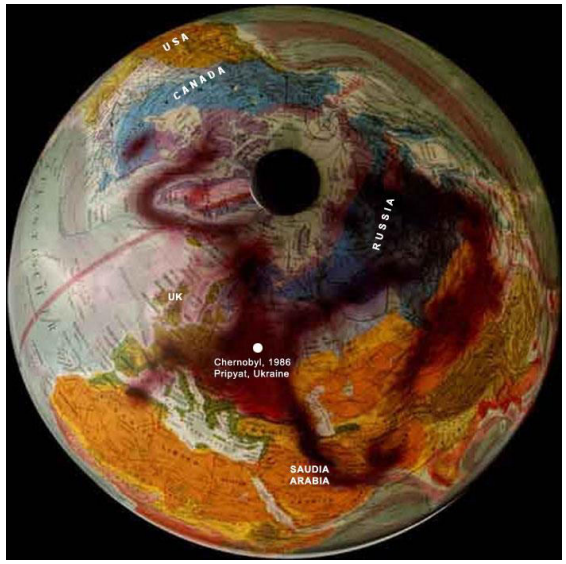
Three Mile Island:

March 28, 1979
near Harrisburg, Pa.
stuck valve in
cooling system.
$500 million cleanup of
site thru 1993.

Chernobyl

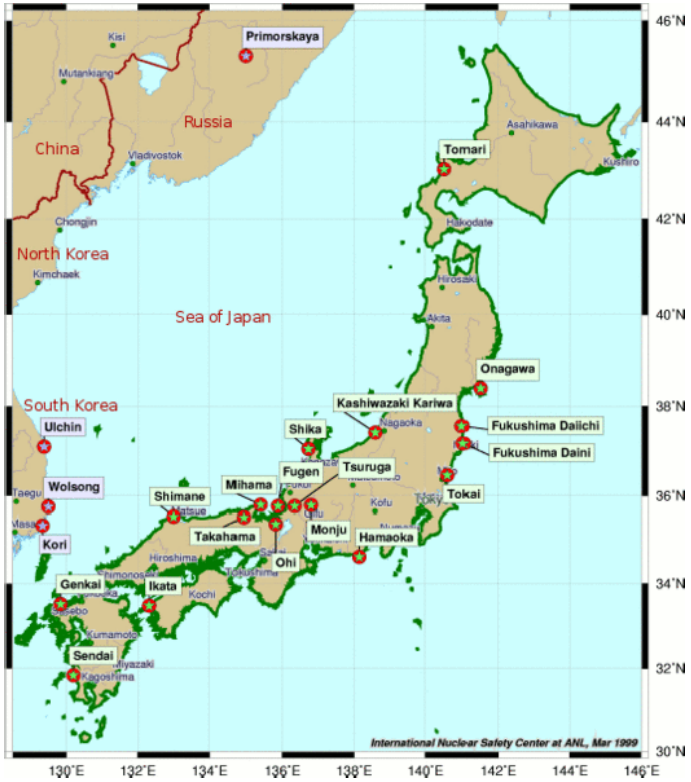
26 April 1986
plume of highly
radioactive smoke
fallout.
50 to 200 thousand
deaths.

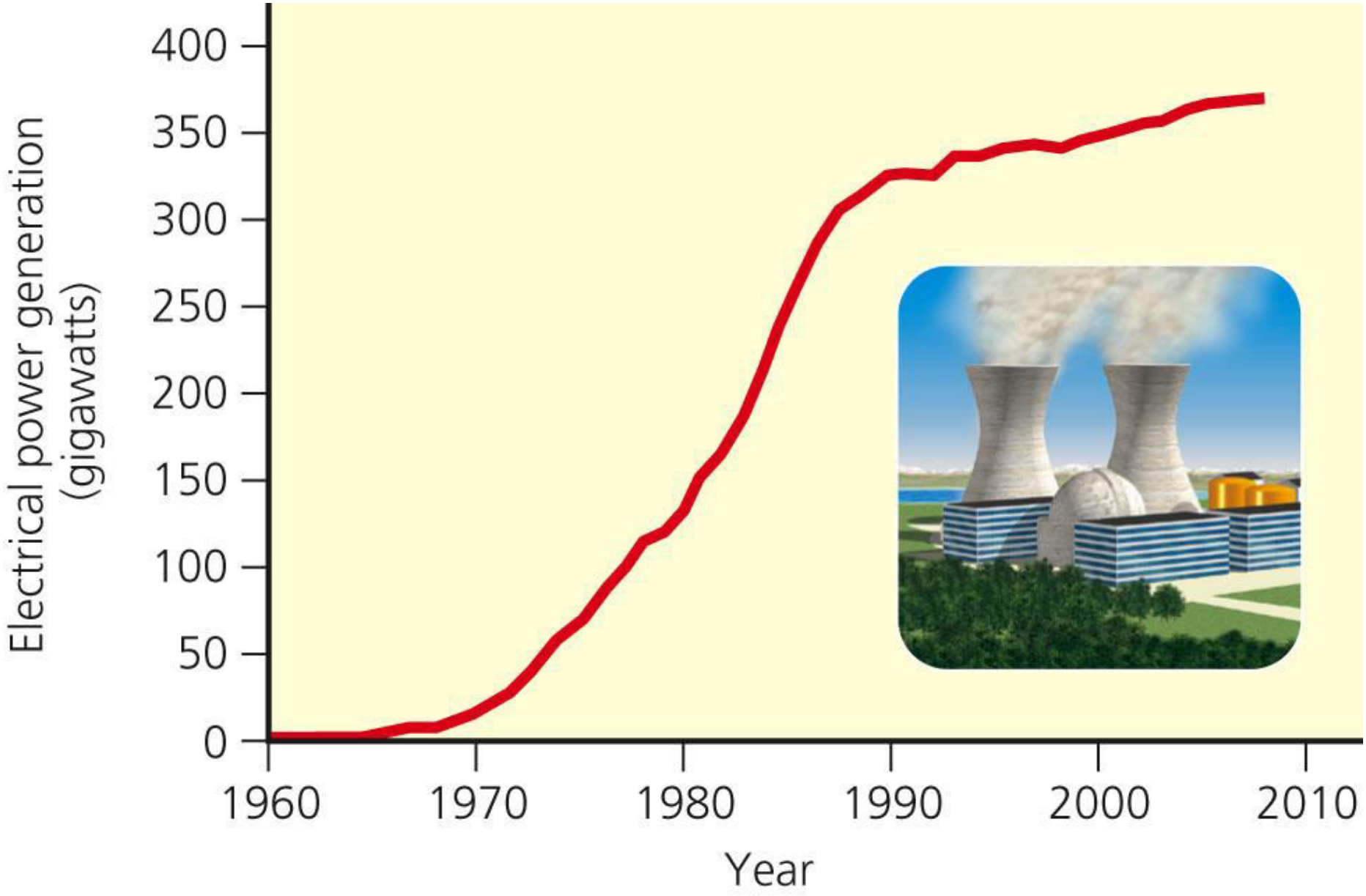




Fukushima Daiichi nuclear disaster 11 March 2011

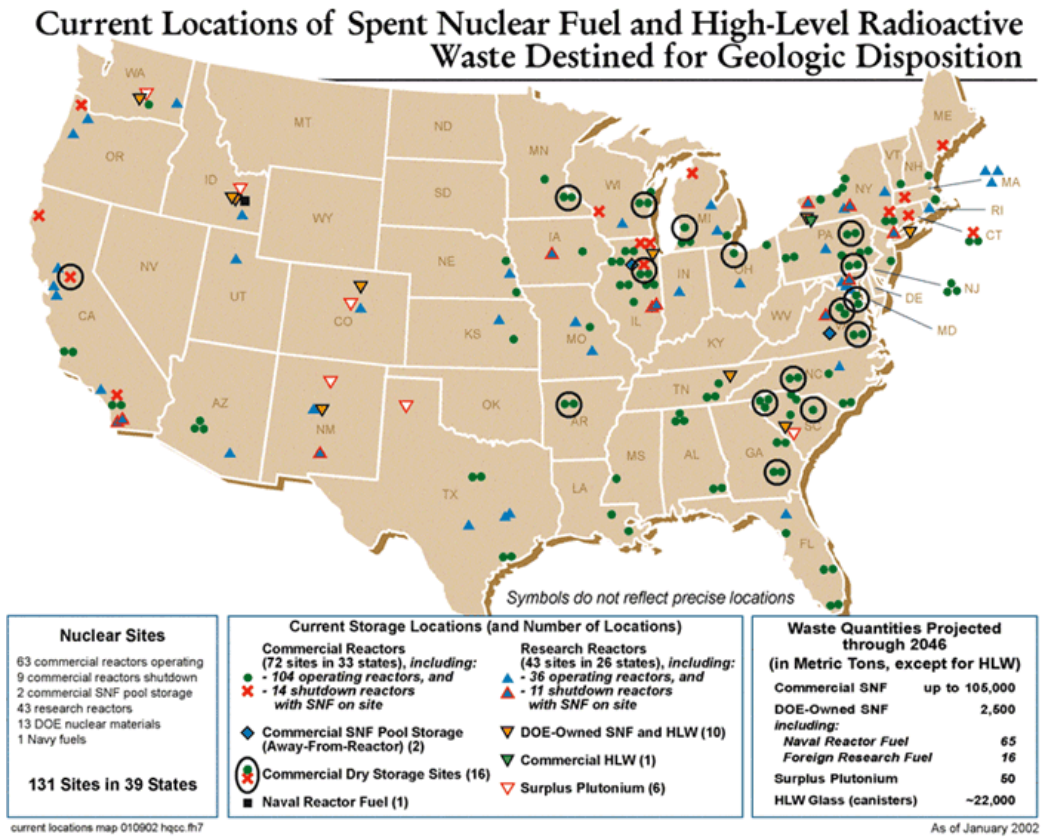
Reactors 1, 2 & 3 experienced full meltdown.




Electrical power generation (gigawatts)
400
350
300
250
200
150
100
50
0
1960
1970
1980
1990
2000
2010
Year

Nuclear Power Is Vulnerable to Terrorist Acts

- Insufficient security
- On-site storage facilities
- U.S.: **161 million people** live within 75 miles of an above-ground nuclear storage site

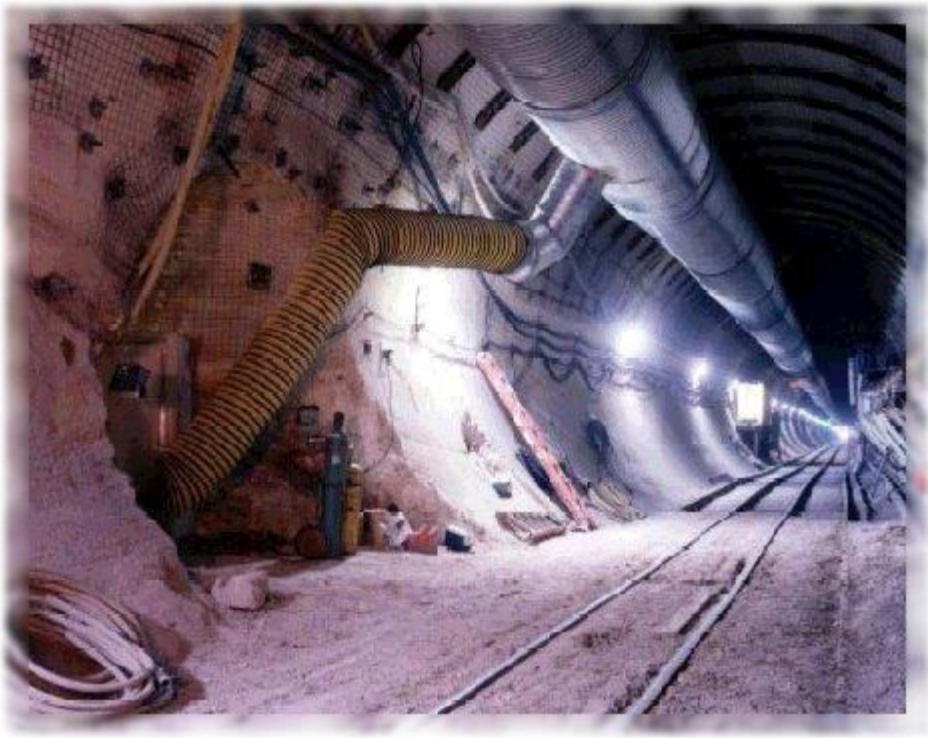


Dealing with Radioactive Wastes

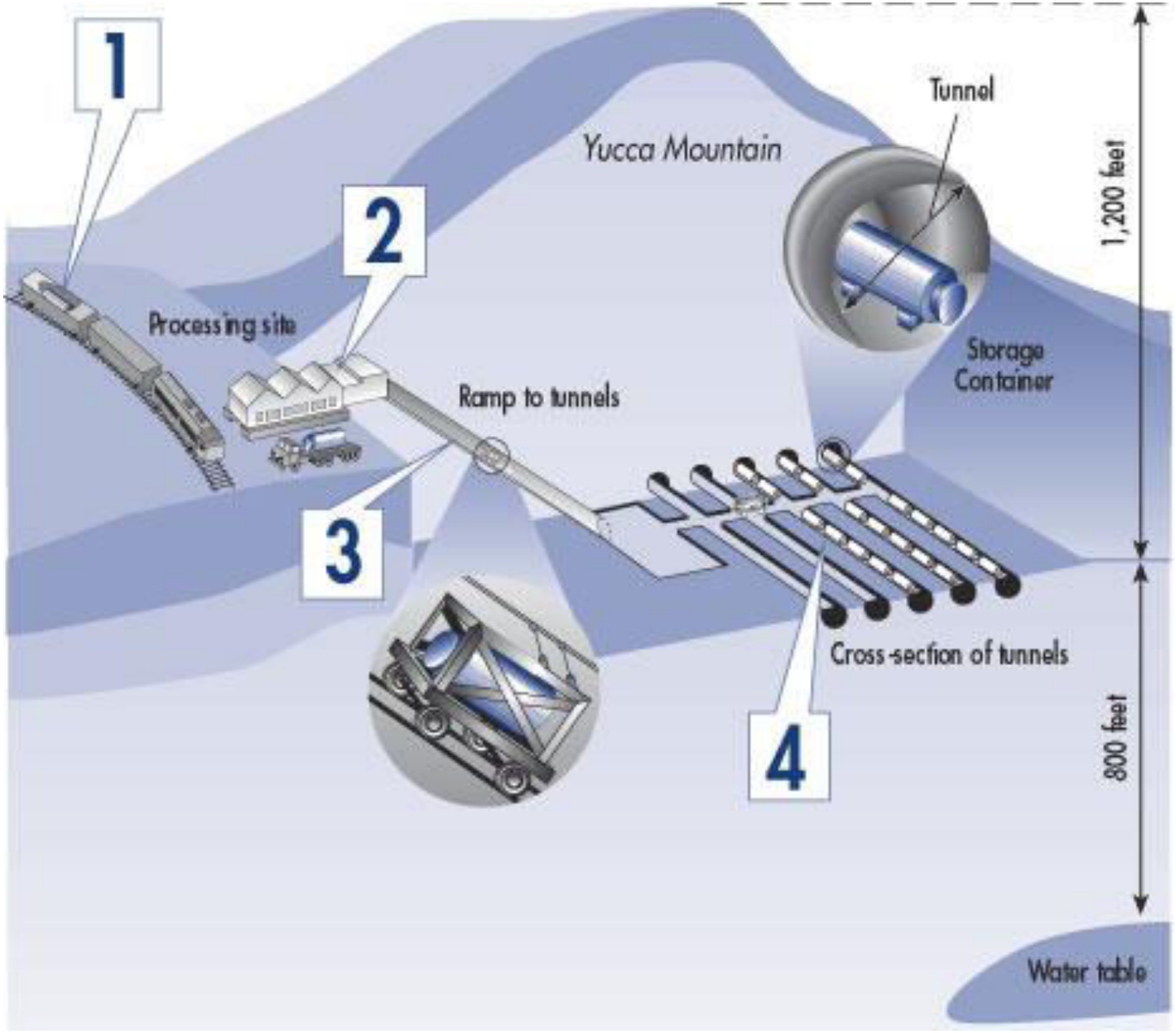
- High-level radioactive wastes
- Long-term storage: 10,000–240,000 years
- Deep burial
- Detoxify wastes?

Case Study: Dealing with Radioactive Wastes in the United States

- Yucca Mountain, Nevada
- Concerns over groundwater contamination
- Possible seismic activity
- Transportation accidents & terrorism



2009: Obama ends Yucca funding


1
2
3
4
Yucca Mountain
Tunnel
1,200 feet
Processing site
Ramp to tunnels
Storage Container
Cross-section of tunnels
800 feet
Water table

What Do We Do with Worn-Out Nuclear Power Plants?

- Decommissioning old nuclear power plants
- Dismantle power plant and store materials
- Install physical barriers
- Entomb entire plant

Chernobyl sarcophagus

What Is the Future for Nuclear Power?

- Reduce dependence on foreign oil
- Reduce global warming
- Advanced light-water reactors
- **Nuclear fusion**
- How to develop relatively safe nuclear power with a high net energy yield?

Why Is Energy Efficiency an Important Energy Source?

- The United States could save as much as 43% of all the energy it uses by improving the energy efficiency of industrial operations, motor vehicles, and buildings.

Improving Energy Efficiency

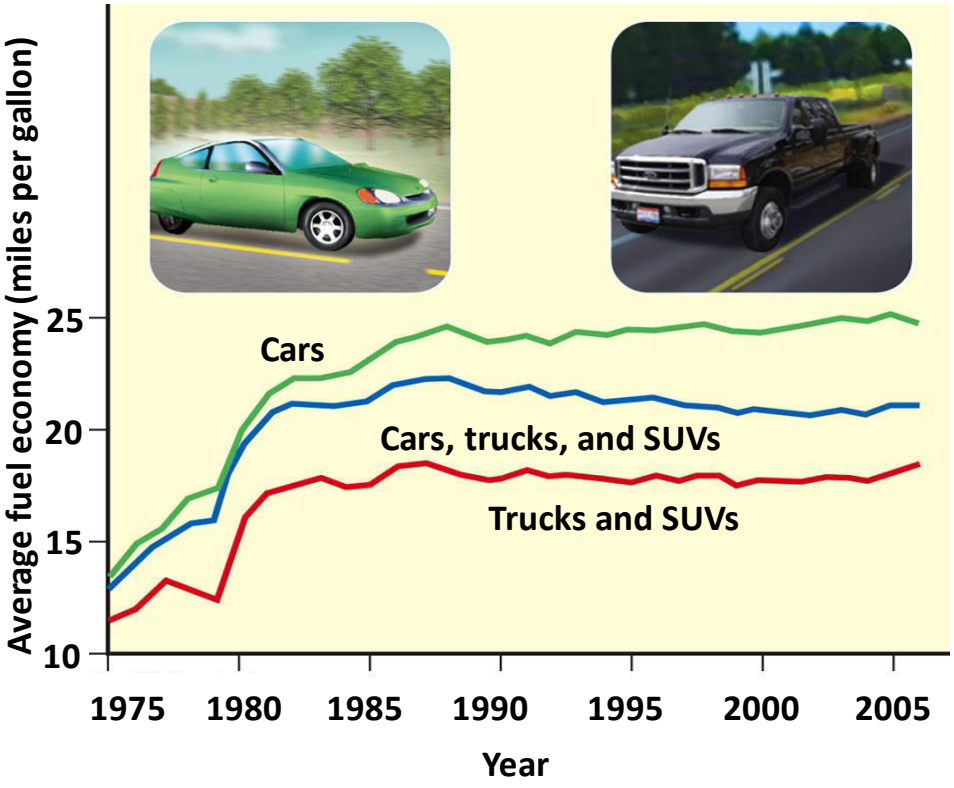
- **Energy efficiency**
  - How much work we get from each unit of energy we use
- Reducing energy waste
  - 41% of all commercial energy in U.S. is wasted unnecessarily
- Numerous economic and environmental advantages

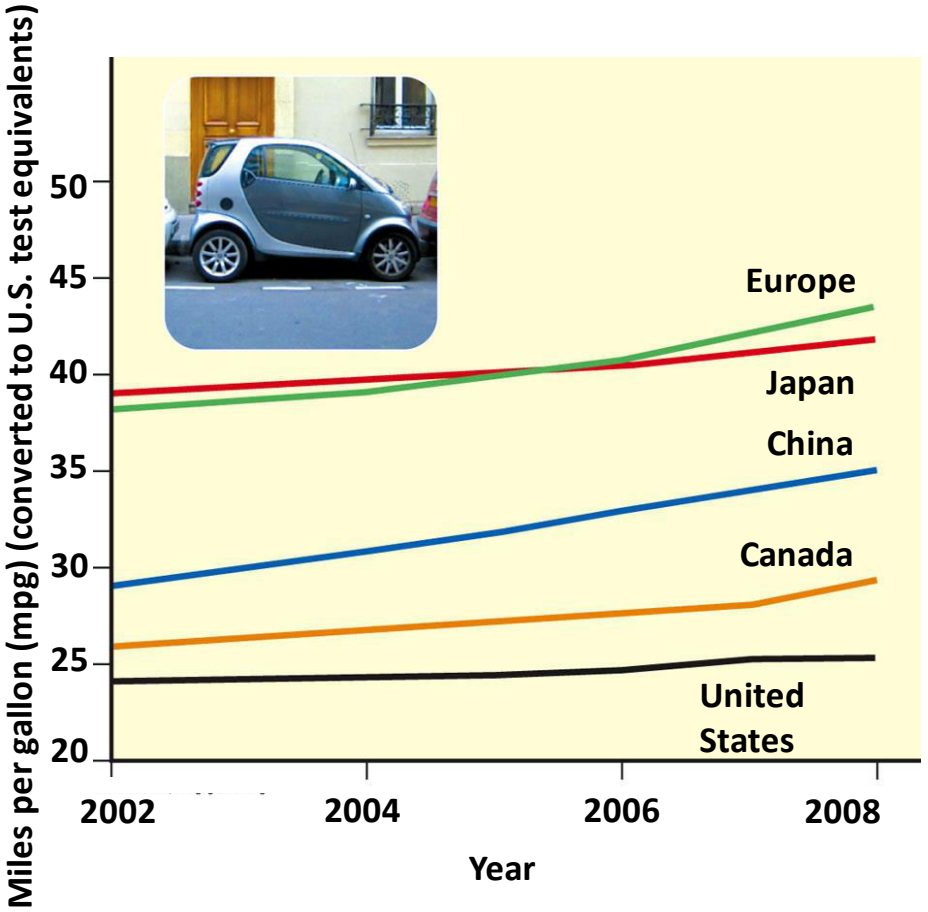
Saving Energy and Money in Transportation

- 2/3 of U.S. oil consumption
- Low fuel-efficiency standards for vehicles
- Hidden costs: $12/gallon of gas
- Raise gasoline taxes/cut payroll and income taxes
- Tax breaks for fuel-efficient vehicles

Hybrid and Fuel-Cell Cars

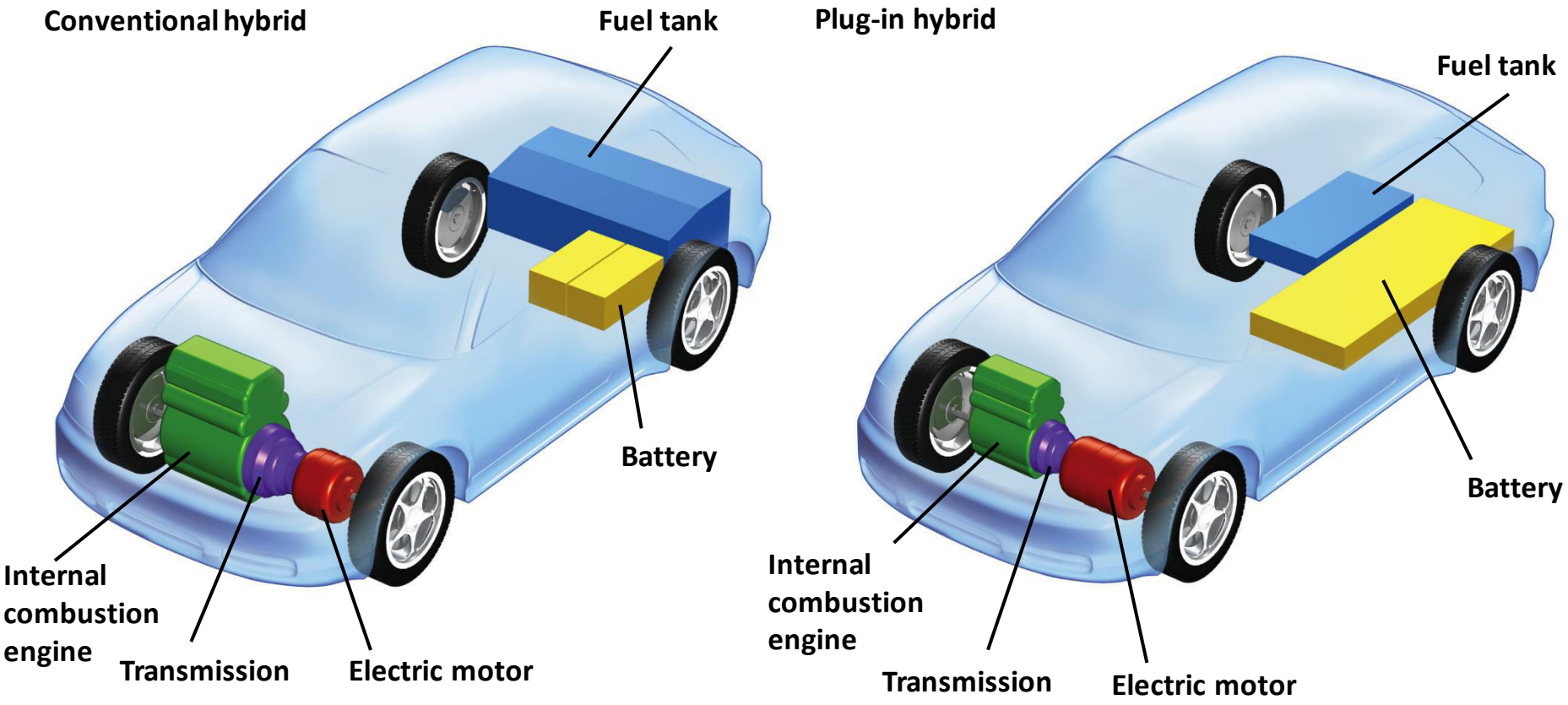
- Super-efficient and ultralight cars
- Gasoline-electric hybrid car
- Plug-in hybrid electric car
- Hydrogen fuel cells
- Accessible mass-transit systems as alternative





Stepped Art

Fig. 13-21, p. 320



Stepped Art

Fig. 13-22, p. 321

Saving Energy and Money in New Buildings

- Green architecture
- Solar cells, fuel cells, eco-roofs, recycled materials
- Super insulation
- Straw bale houses

Renewable Energy

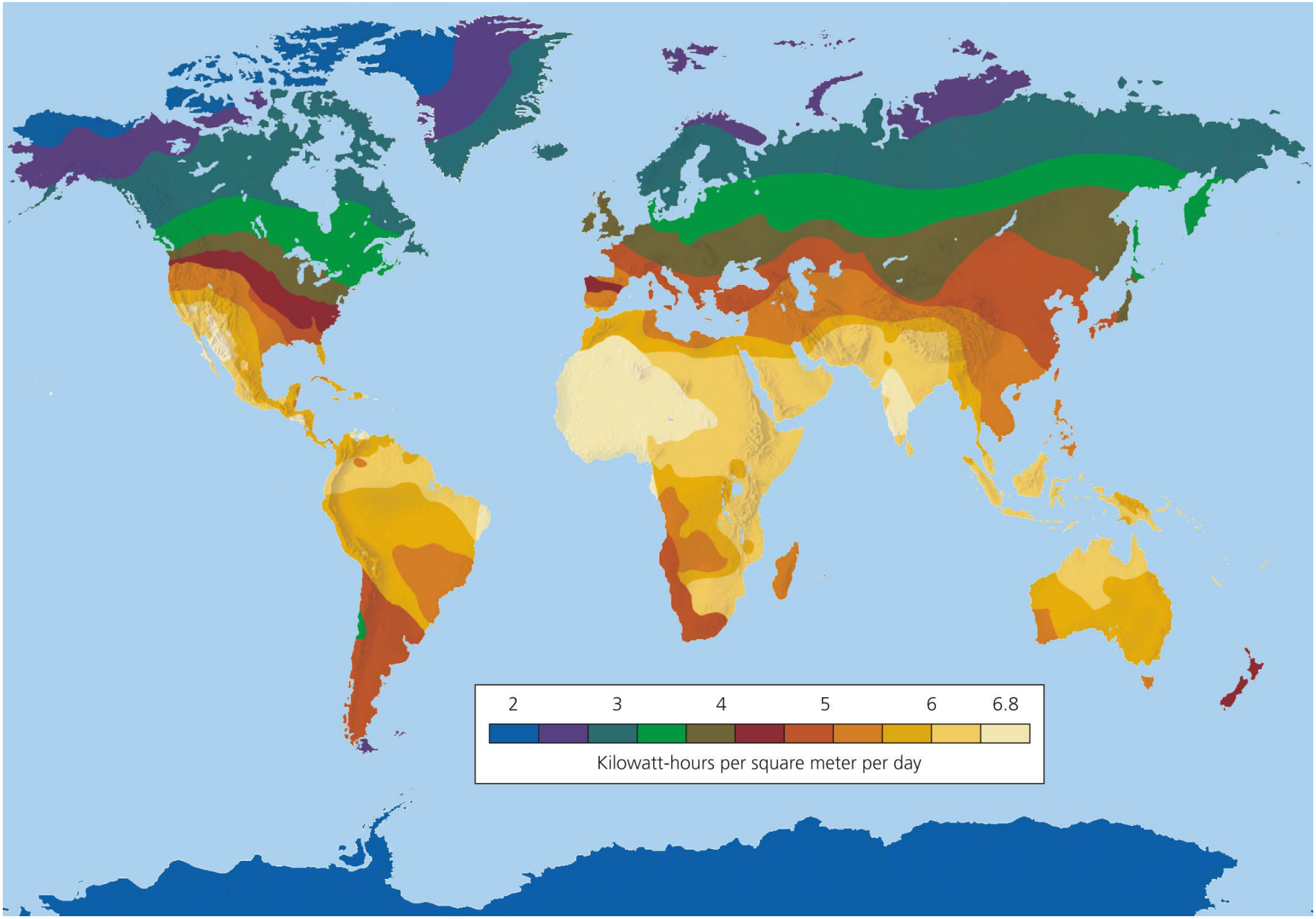
- Sustainability mostly depends on solar energy
  - Direct form: from the sun
- Indirect forms
  - Wind
  - Moving water
  - Biomass
- Geothermal

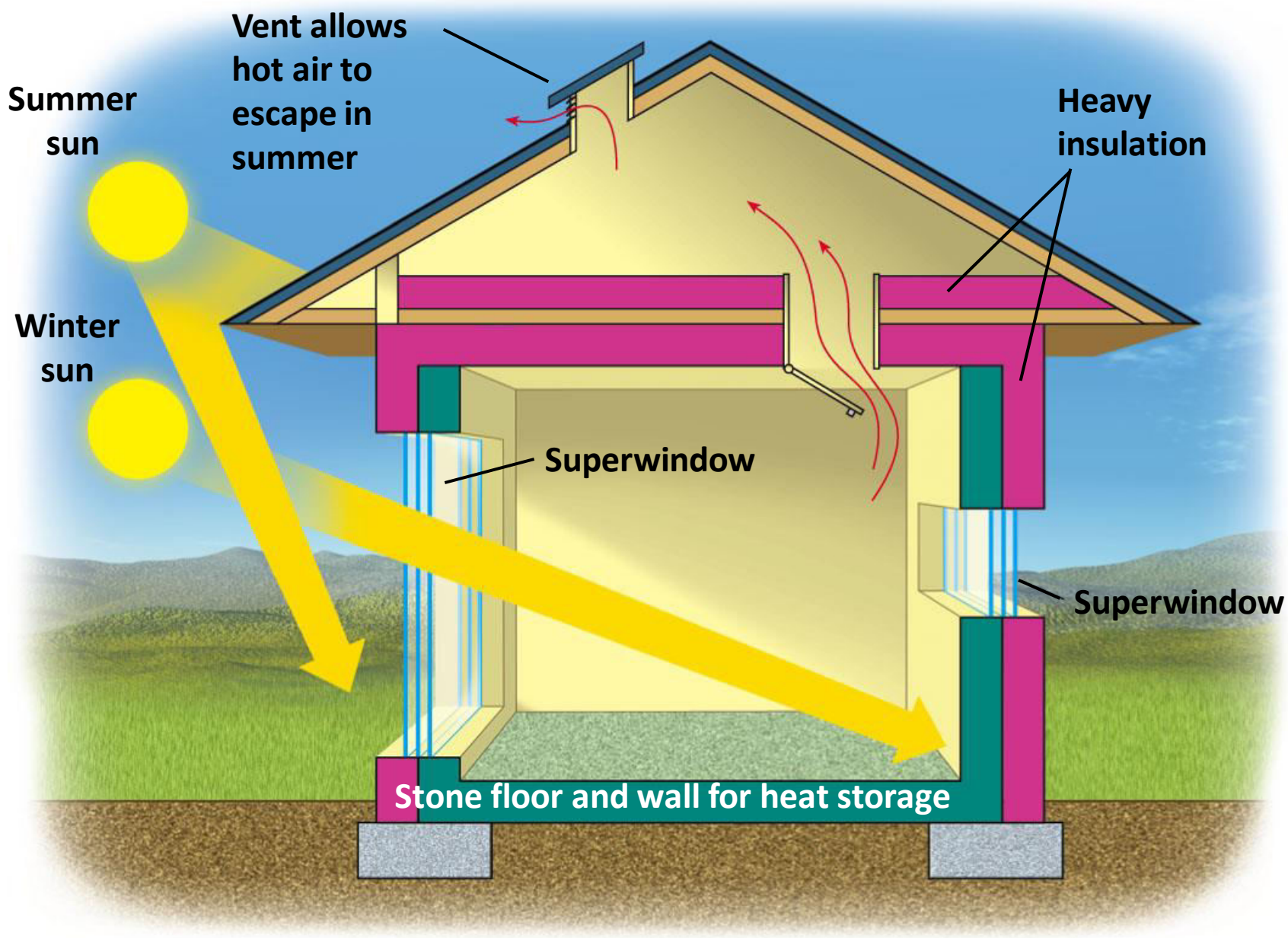
Benefits of Shifting to Renewable Energy Resources

- More decentralized, less vulnerable
- Gradual shift from centralized macropower to decentralized micropower = $ shift!
- Improve national security
- Reduce trade deficits
- Reduce air pollution

Using Solar Energy to Heat Buildings and Water

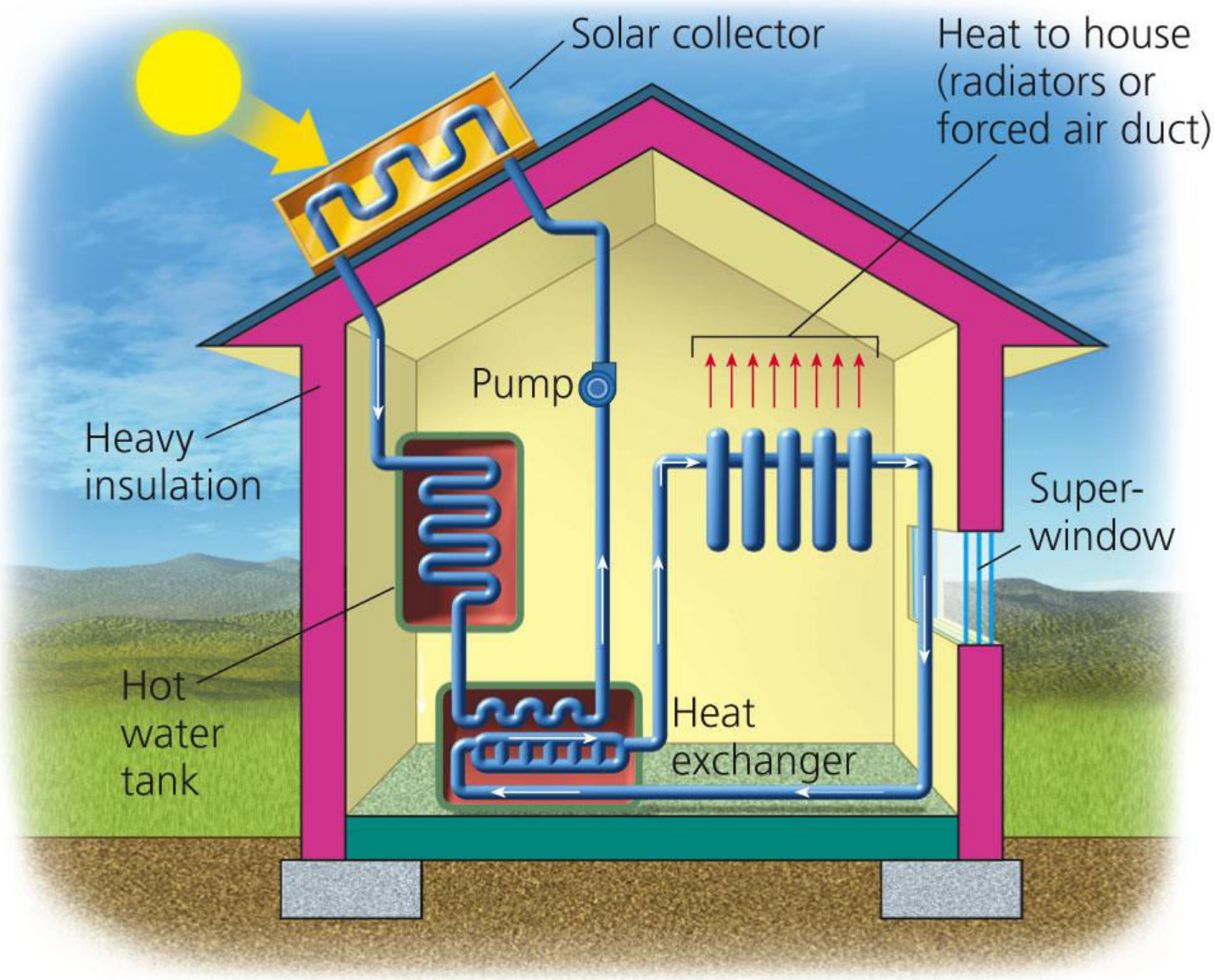
- **Passive solar heating system**
- **Active solar heating system**


2
3
4
5
6
6.8
Kilowatt-hours per square meter per day



PASSIVE

Fig. 13-25, p. 325

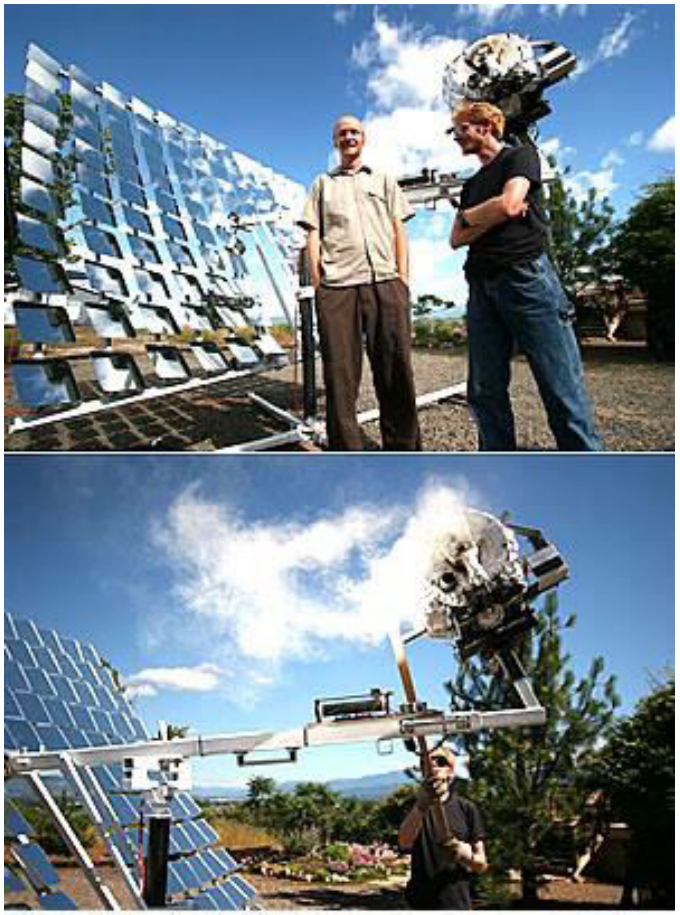


ACTIVE

Fig. 13-25, p. 325

Solar Energy for High-Temperature Heat and Electricity

- Solar thermal systems
- Solar thermal plant
- Solar cookers
- Photovoltaic (solar) cells



Mike & David Hartkop

Trade-Offs

Solar Energy for High-Temperature Heat and Electricity

Advantages

Moderate environmental impact

No CO_2 emissions

Fast construction (1–2 years)

Costs reduced with natural gas turbine backup

Disadvantages

Low efficiency

Low net energy

High costs

Environmental costs not included in market price

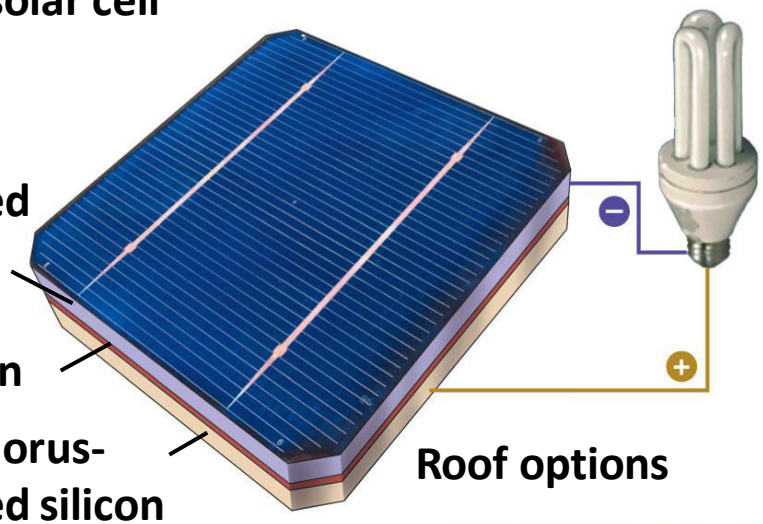
Needs backup or storage system

Needs access to sun most of the time

May disturb desert areas

Fig. 13-27, p. 326

Single solar cell



Solar-cell roof

Roof options

Panels of solar cells

Solar shingles

Fig. 13-29, p. 328

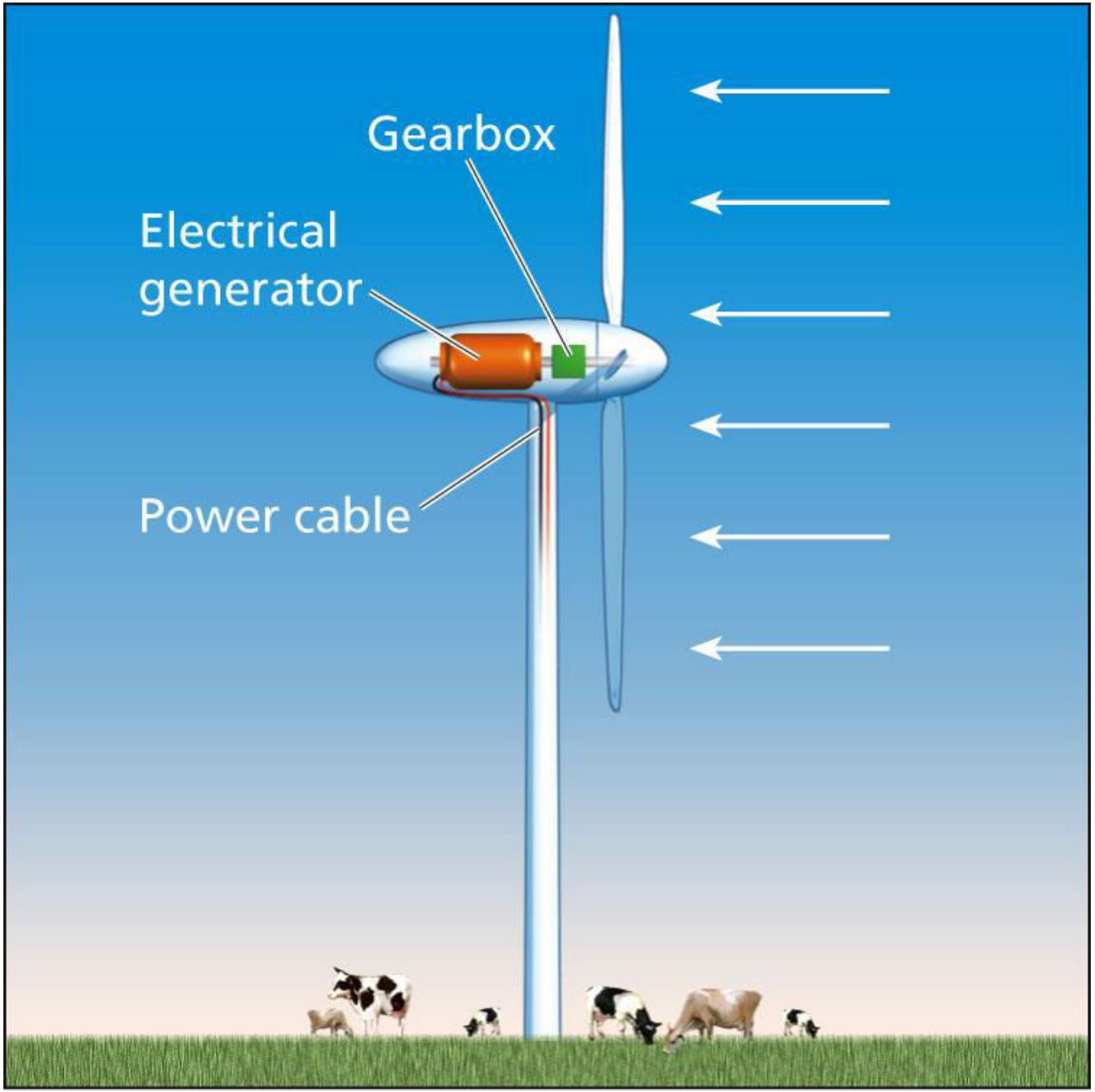
Fig. 13-30, p. 328

Producing Electricity from Flowing Water

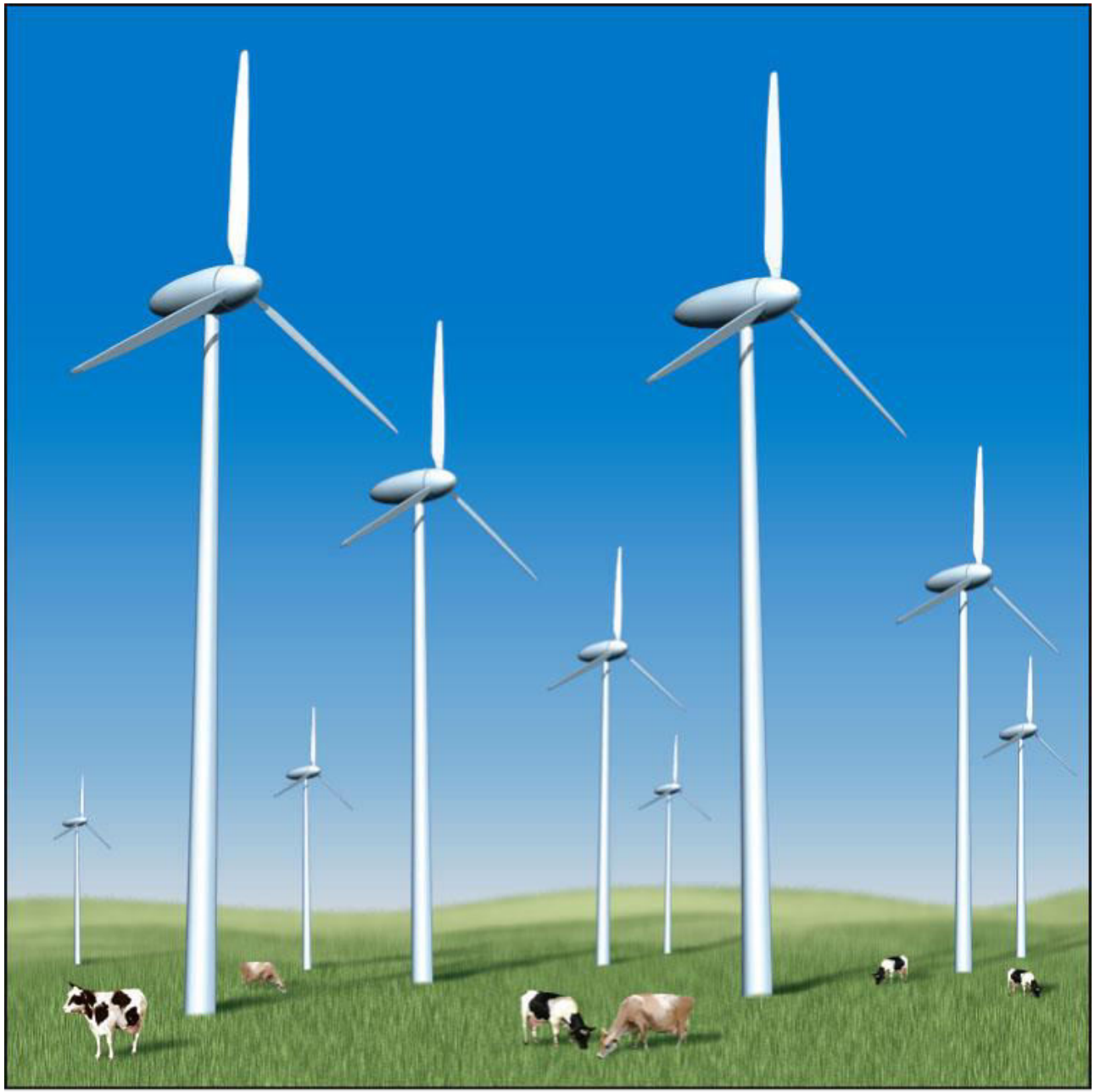
- Hydropower
  - Leading renewable energy source
  - Much unused capacity
- Dams and reservoirs
  - Turbines generate electricity
  - Eventually fill with silt
- Micro-hydro generators

Producing Electricity from Wind

- **Indirect** form of solar energy
- World's **second fastest-growing** source of energy
- Vast potential
  - Land
  - Offshore

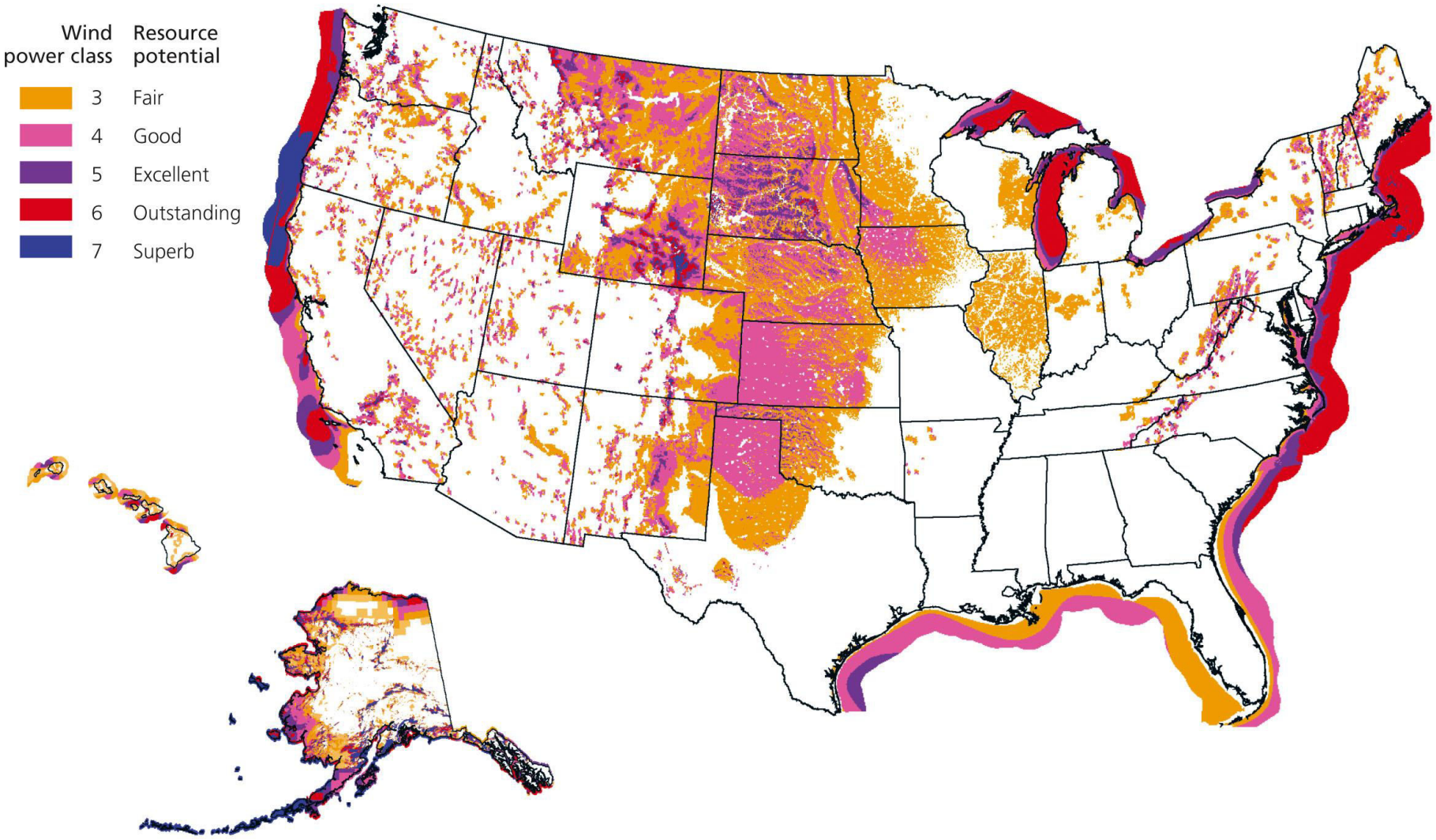


Wind turbine



Wind farm

Wind farm (offshore)



Supplement 9, Fig. 8, p. S43

Energy from Burning Biomass

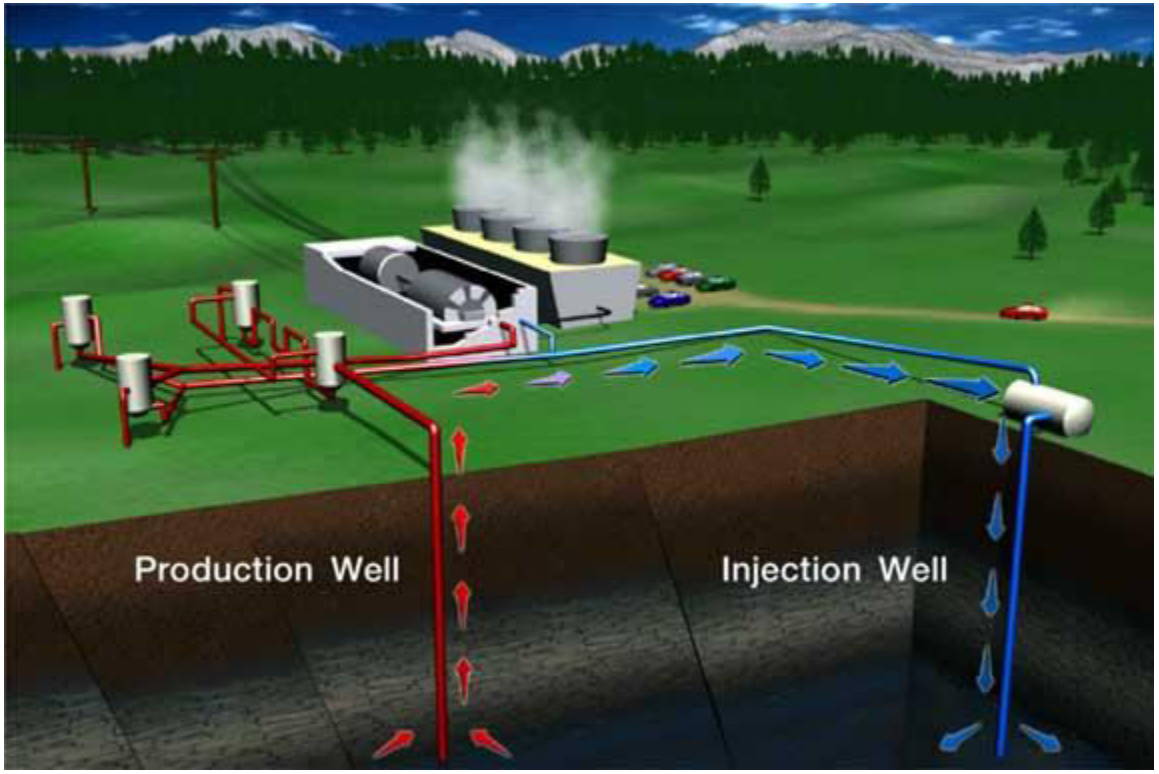
- Biomass
  - Wood
  - Agricultural waste
  - Plantations
  - Charcoal
  - Animal manure
- Common in developing countries
- Carbon dioxide increase in atmosphere

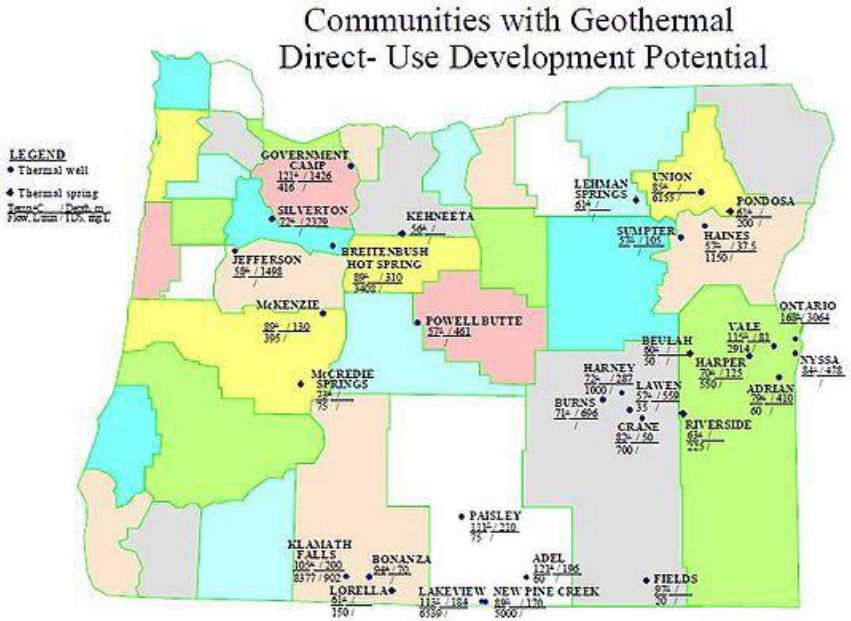
Converting Plant Matter to Liquid Biofuel

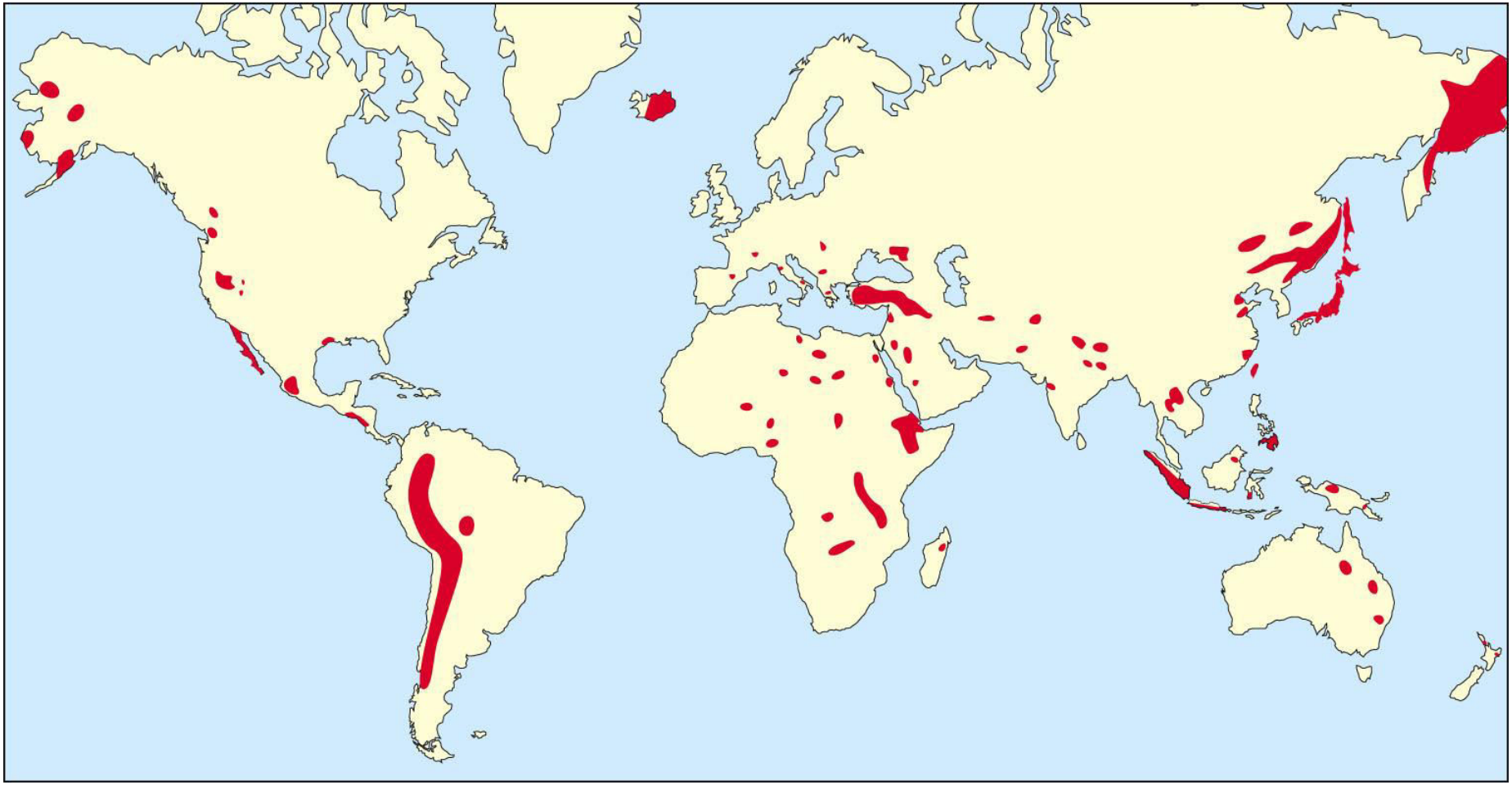
- Biofuels
  - Ethanol and biodiesel
  - Crops can be grown in most countries
  - No **net increase** in carbon dioxide emissions
  - Available now
- Sustainability

Energy by Tapping the Earth's Internal Heat

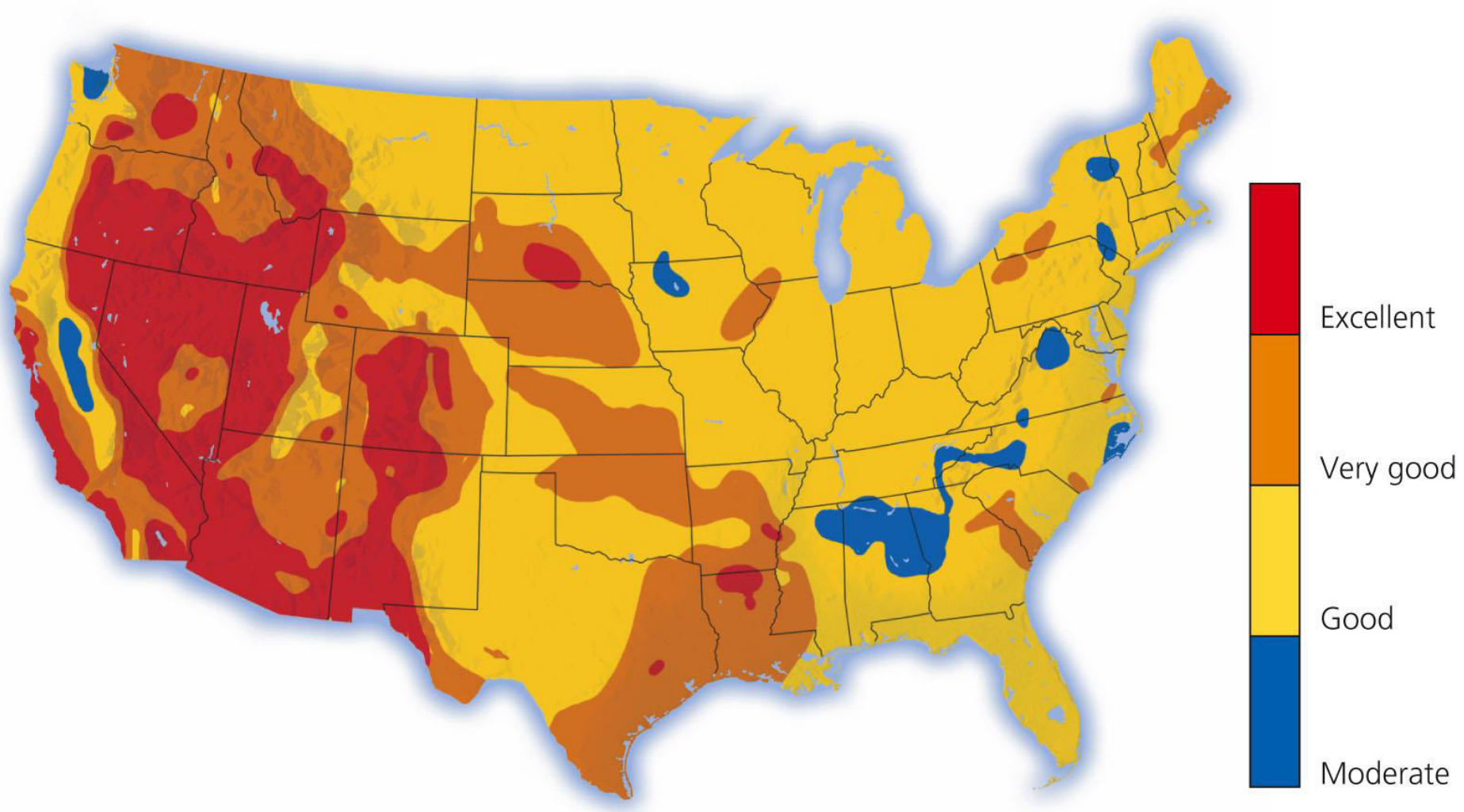
- **Geothermal energy**
- Geothermal heat pumps
- Hydrothermal reservoirs
  - Steam
  - Hot water
- Deep geothermal energy


Production Well
Injection Well


Communities with Geothermal
Direct- Use Development Potential
LEGEND
Thermal well
Thermal spring
GOVERNMENT CAMP
SILVERTON
KEHNEETA
LEHMAN SPRINGS
UNION
PONDOSA
SUMPTER
HAINES
JEFFERSON
BREITENBUSH HOT SPRING
McKENZIE
POWELL BUTTE
ONTARIO
VALE
BEULAH
NYSSA
HARPER
HARNEY
LAWEN
ADRIAN
BURNS
CRANE
RIVERSIDE
McCREDIE SPRINGS
PAISLEY
KLAMATH FALLS
BONANZA
ADEL
FIELDS
LORELLA
LAKEVIEW
NEW PINE CREEK



Supplement 9, Fig. 9, p. S43



Supplement 9, Fig. 10, p. S44

Can Hydrogen Replace Oil?

- Hydrogen is environmentally friendly
- Problems
  - Most hydrogen is in water
  - Net energy yield is negative
  - Fuel is expensive
  - Air pollution depends on production method
  - Storage

Science Focus: The Quest to Make Hydrogen Workable

- Bacteria and Algae
- Electricity from solar, wind, geothermal
- Storage: liquid and solid
- Preventing explosions

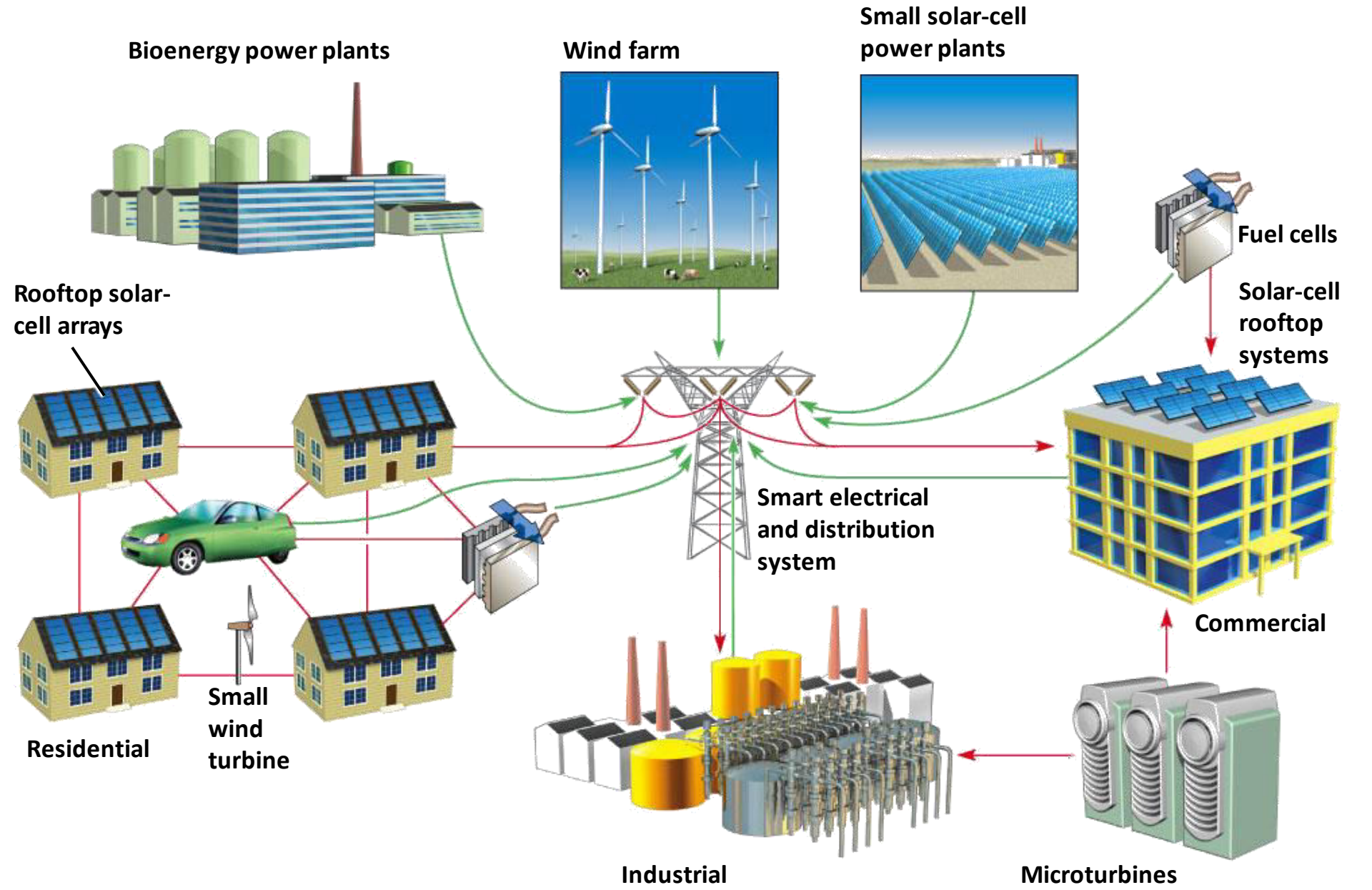


Fig. 13-40, p. 339

Transition to a More Sustainable Energy Future

- Gradual shift from centralized macropower to decentralized micropower
- Greatly improved energy efficiency
- Temporary use of natural gas
- Decrease environmental impact of fossil fuels